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ORIGINAL ARTICLES.

I.—Eminent Living Geologists.

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(WITH A PORTRAIT, PLATE XVI.)

WILLIAM WHITEHEAD WATTS was born at Broseley in Shropshire in 1860, and passed the critical part of his school life at Denstone. Here he came under the influence of the Rev. D. Edwardes, who taught him physics and chemistry, infected him with a love of science, and stimulated him to try for a scholarship at Cambridge. In spite of the winning of an exhibition, afterwards converted into a scholarship at Sidney Sussex College, supplemented by an exhibition from his old school, his maintenance at Cambridge was only accomplished by much self-sacrifice on the part of his parents.

By great good fortune it happened that J. F. Walker had that year been recalled to Sidney as Lecturer in Chemistry, and as young Watts kept in the rooms immediately beneath him the two soon became fast friends. Walker advised his pupil to dilute his study of chemistry with a little geology, and thus, by accident or design, gave him a chance to see that the subject was neither so dull nor so useless as he had previously supposed it to be. Work at the Woodwardian Museum under the stimulating teaching of Professors Hughes and Bonney, of Tawney and R. D. Roberts, coupled always with the friendly advice, assistance, and encouragement of Walker himself, soon made geology occupy the chief place in his time and thoughts, so that he adopted it for the final subject for his degree.

Another potent factor in the same direction was the foundation of the "Sedgwick Club" by a number of contemporaries, chief of whom were Middlemiss, Harker, and Tom Roberts, one of the few Cambridge clubs which has celebrated its 25th birthday and is now well on the way to its jubilee. It numbers most of the well-known Cambridge geologists among its members, and still meets for the discussion of papers and for excursions, among which those to Charnwood and Nuneaton have been conducted by one of the earliest presidents.

When, at the end of 1881, he had obtained a first class in Geology in the Natural Science Tripos, Watts was offered immediate work on the University Extension by R. D. Roberts, and left Cambridge to

lecture to an audience of school-girls at Southport. He remained on the University Extension till 1891, lecturing on Physical Geography and Prehistoric Archæology, as well as on Geology and subjects closely related to it, at many towns in the north, west, and south-east of England as well as in the Midlands.

In 1882 Watts assisted J. E. Marr to fill the post of Professor Green during his absence from Leeds; in 1883–4 he acted as Deputy-Professor at the Mason College, Birmingham, during the illness of Professor Lapworth; and in 1888 as deputy at Oxford after the resignation of Professor Prestwich and before Professor Green was able to begin his work there. He also lectured during two bye-terms at Cambridge and obtained some experience of class-teaching at his old school, thus becoming acquainted with most sides of teaching work and with the methods and conditions of many men and institutions.

In 1891 the wander-period closed and Watts accepted an appointment on the staff of the Irish Geological Survey offered him by Sir Archibald Geikie. In addition to routine work he was specially charged with the care of the Survey Collections in the National Museum in Dublin, an unrivalled opportunity to become acquainted with the geology of the country. When this work was completed he was transferred to the English Survey, where he acted as petrographer in the room of Dr. Hatch until 1897.

In that year an assistant-professorship was founded to relieve Professor Lapworth of part of his routine work at the Mason College. Watts was selected for this post and for nine years had the privilege of assisting Lapworth in the teaching of geology and geography. In 1904 he was given a seat on the Senate and the title of Professor of Geography in the newly constituted University of Birmingham.

In 1906, on the resignation of Professor Judd from his chair at the Royal College of Science in London, the Crown appointed Watts to the vacant chair. Later the College was, with the Royal School of Mines and the Central Technical College, reconstituted as the Imperial College of Science and Technology and Watts was continued as Professor.

He was married in 1889 to Louisa Adelaide, the daughter of Colonel H. A. Atchison, who died in 1891, and in 1894 to Rachel, the widow of Arthur Turnour Atchison, Assistant Secretary to the British Association.

Watts' first original work was the outcome of a remark dropped by a geologist on seeing the Breidden Hills for the first time from the Wrekin, that they were "merely a mass of amygdaloidal basalt". The fortunate discovery of andesitic tuffs and of fossils gave a clue to the age and succession of the rocks and resulted in a paper published by the Geological Society. Professor Lapworth determined the graptolites found and permitted Watts to share in many weeks of delightful field-work on the cognate igneous rocks of the neighbouring Shelve district, culminating in the discovery that the igneous masses were of laccolite or, as it would now be termed, phacolite form. After this work Lapworth passed down the sequence to Church Stretton and the Longmynd and Watts upward to the Silurian deposits of the Long Mountain, but the two came together on more

than one occasion in general descriptions of the Shropshire and Birmingham districts, and in excursions of the British and Geologists' Associations to these regions.

On the Geological Survey, aside from descriptions of igneous and other rocks for the publication of maps, reports, and memoirs, Watts carried out three principal pieces of work. The first was the examination of the large suites of rocks collected by Jukes and others all over Ireland and deposited in the Survey Museum in Dublin. Very many types were discovered and briefly described in the Museum Guide, and the collections, with others specially made to supplement them, were arranged in the Museum.

On the English Survey Watts was associated with Mr. Lamplugh's work on the Crush-conglomerates of the Isle of Man, and joined with that geologist in his descriptions of them and of other igneous and metamorphic rocks in the island. He was also charged with the mapping and description of the ancient rocks of Charnwood Forest. He succeeded in supplementing existing knowledge on the succession of the rocks, their tectonic structure, and their place in the sequence; but the more interesting part of his work was to bring out the evidence that the region had stood out as a mountainous archipelago from the Carboniferous sea and the Permian and Trias lakes, and that the striking landscape of the district was a fossil landscape still preserving the features impressed upon it by the dry denudation and desert sandstorms of Triassic times.

As early as 1888 Watts had been struck by the importance of photographic records to the geologist, and he took up warmly the work initiated by O. W. Jeffs at the British Association at Bath. Eventually in 1895 he undertook the joint and afterwards the sole secretaryship of the Geological Photographs Committee, and issued eleven reports on the photographs thus brought together and stored at the Museum of Practical Geology. The quality of geological photography steadily improved, and in 1900 the Committee decided on the publication of sets of prints and slides of typical geological photographs accompanied by descriptions by authorities on the subjects represented. Watts acted as editor and publisher of the series which was completed in 1904, and met with great success. Now "British Geological Photographs" form the basis of teaching-sets all over the world.

In 1886 Watts became one of the secretaries of Section C of the British Association, in association with W. Topley, whom he succeeded as recorder in 1889. This office he held until 1894, a most valuable experience which brought him into friendly relations with many of the leading English and Foreign geologists.

He became Chairman of the Conference of Delegates in 1902, and President of Section C in 1903 at Southport, when his address was devoted to geological education and its value to the community.

It was in 1898 that he undertook the duties, including the abstracting of papers, of Secretary of the Geological Society, and remained in that office till 1909. The chief event of this period was the celebration of the centenary of the Society in 1907, for which he undertook a considerable share of the organization, and in 1909

published the official account. In 1910 he was elected President of the Society and delivered two addresses, the first dealing with geology as an evolutionary science, the second with the problem of coal supply. His period of office was also marked by the transfer of the Society's collections to the Museums of Natural History and Practical Geology, and the consequent extension of the Library.

As President of the Geologists' Association during its Jubilee (1908) and the following year, Watts delivered two addresses dealing with the history and the work of the Association. He was also present when this body visited the Paris Basin under the genial guidance of M. Dollfus.

Watts had the good fortune to be at Birmingham during the growth of the Mason College into Birmingham University; at South Kensington when the School of Mines developed into the Imperial College; and in London during the recent expansion of its University, acting part of the time as Chairman of the Board of Studies in Geology and later as Dean of the Faculty of Science, and sitting on the Senate and the Academic Council. He was further fortunate in fitting into the admirable teaching scheme of Lapworth at Birmingham, and in succeeding to the eminently practical methods of Judd. The experiences thus gained, coupled with the training of the University Extension, at a school, and at other Universities, has naturally reacted on his own teaching and intensified its practical and economic sides. This is illustrated by his book *Geology for Beginners*, 1898, but the chief outcome has been the establishment at the Imperial College of a Chair of Economic Mineralogy, occupied by C. G. Cullis, the initiation of a school of Oil Technology, and the bringing of the teaching into close relations with the other technological work of the Imperial College.

Professor Watts has served on the Councils of many Scientific Societies, the Royal, Geological, Geographical, Mineralogical, and Palæontographical, as well as the Geologists' and British Associations. He served on the Funafuti Committee of the Royal Society and had much to do with the organization of the Reef-drilling expedition; while as a member of the Education Committee of Sutton Coldfield he superintended the erection and equipment of the technical school there. He has acted as examiner in Geology to the Universities of Oxford, Cambridge, London, Durham, Leeds, Wales, Ireland, and New Zealand, and in Geography at Cambridge and London. He has been Secretary and President of the Vesey Club, and President of the Sutton Scientific Society, the Geographical Section of the Birmingham Natural History Society, and the Birmingham Naturalists' Union.

He joined the Geological Society in 1882, received the Wollaston Fund in 1895, and the Murchison Medal in 1915. The official degree of M.Sc. was conferred on him at Birmingham in 1902, that of Sc.D. at Cambridge in 1908, and the honorary degree of LL.D. as the representative of the Geological Society at the Tercentenary gathering at St. Andrews in 1911. He became a Fellow of the Royal Society in 1904, was elected to a Fellowship at Sidney Sussex College in 1888, and was made an Honorary Fellow of his old College in 1910.

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II.—Suggestions for a Revised Classification of Trilobites.

By H. H. SWINNERTON, D.Sc., F.G.S., F.Z.S., Professor of Geology, University College, Nottingham.

Introduction.

IN 1897 C. E. Beecher[1] published his "Outline of a Natural Classification of the Trilobites", which has since "proved superior to any previously proposed". Nearly a score of years have passed since that time and many new Trilobites have been discovered, the majority of which fit into this system without difficulty and prove that to a large extent it is conceived on a sound basis. A few, however, do not fit in and have therefore revealed in it weaknesses, the existence of which tend to hinder the systematic study of Trilobites. In the following pages it is proposed to point out these weaknesses and to make suggestions for modifying and extending Beecher's system upon what it is hoped will prove to be natural lines.

On the whole the families given by Raymond in the 1913 edition of Zittel's *Textbook of Palæontology* as edited by Eastman will be used as the basis for this discussion.

Recent Classifications.

Beecher's classification has been adopted without modification of its broad lines by English and American, but not by all Continental writers. Among the latter Gurich[2] and Jaekel[3] have recently suggested systems which differ materially from Beecher's.

[1] *Amer. Journ. Sci.*, vol. iii, 1897.
[2] *Centralblatt Min. Geol. Palaeont.*, 1907, p. 129.
[3] Zeitsch. Deutsch. geol. Ges., Bd. lxi, p. 380, 1909.

That of Gurich is as follows :—

Order TRILOBITA.
Series *Oligomeria* :—With few free trunk segments.
Sub-order 1. *Isopygia*. Pygidium about the same size as the cephalon.
Agnostidæ, Microdiscidæ.
Sub-order 2. *Heteropygia*. Pygidium distinctly smaller than the cephalon.
Trinucleidæ, Ampycinæ, Dionidæ, Æglinæ.
Series *Pliomeria* :—With many free trunk segments.
Sub-order 3. *Micropygia*. Pygidium very small.
Olenellidæ, Paradoxidæ, Remopleuridæ, Ellipsocephalidæ, Harpedidæ, Olenidæ, Arethusinidæ, Cyphaspidæ.
Sub-order 4. *Macropygia*. Pygidium large, often equal to the cephalon.
Group *a*. Opisthoparia.
Proetidæ, Dicellocephalidæ, Lichidæ, Acidaspidæ, Bronteidæ, Asaphidæ.
Group *b*. Gonatoparia. Suture cuts genal angle.
Homalonotidæ, Calymmenidæ.
Group *c*. Proparia.
Phacopidæ, Cheiruridæ, Encrinuridæ.

Jaekel, after a careful study of the Agnostidæ, considers that these Trilobites are sufficiently distinct from all others to be placed in a separate division equal in value to that containing all other Trilobites. He therefore proposes the name Miomera for those which, like Agnostidæ and Microdiscidæ, have only three trunk segments, and Polymera for all with six or more free segments.

Beecher's Classification.

The developmental details upon which Beecher's classification is based are too well known to justify recapitulation here. It will suffice to recall the facts that in the earliest larval stages of both opisthoparian and proparian Trilobites the free cheeks are not seen on the dorsal side, but that, as development advances, the facial suture appears first of all close to the margin and then moves towards the glabella, so that the free cheek, at first narrow, broadens out. It is therefore assumed—whether rightly or wrongly the future will decide—that in the earliest stages the free cheeks are on the ventral side and that the sutures run either along or below the margin. It is further assumed that the occurrence of this hypothetical phase in so many widely separated Trilobites is due to there having been a corresponding stage in the evolution of both the Opisthoparia and the Proparia. This leads naturally to the supposition that this hypoparian condition might have been retained into adult life by some known Trilobites, hence the creation of the division Hypoparia. Whilst the divisions Opisthoparia and Proparia are almost above reproach the same cannot be said of the division Hypoparia.[1] Even Gurich to some extent recognizes the two former, but rejects the latter.

The Hypoparia.

In the English edition of Zittel's textbook the following families are placed under the order Hypoparia: Agnostidæ, Eodiscidæ (Microdiscidæ), Shumardiidæ, Harpedidæ, Trinucleidæ, Raphiophoridæ.

[1] Cf. H. Woods, Cambridge Natural History, vol. Crustacea, ch. Trilobites, pp. 226, 244.

According to the definition of the last-named family there are "small free cheeks visible upon the dorsal surface".[1] If figures are to be trusted the members of this family are as typically opisthoparian as are *Conocoryphe* and *Atops*. Presumably they are placed here because of their evident relationship to the Trinucleidæ.

Among the Trinucleidæ two lines have been described as facial sutures, one which has only occasionally been found and which pursued the course of an advanced opisthoparian type, viz. across the cheek from the anterior of the glabella to the posterior margin. The other ran along the margin of the cephalon. Barrande discussed the relative merits of the two lines, and concluded that the former was only an ornamental nervure and that the latter was the true suture. During recent years evidence has accumulated which shows that Barrande[2] was in error.

The first piece of evidence is negative and suggestive rather than conclusive. If the marginal line be the facial suture, then the dorsal portion of the broad marginal limb belongs to the fixed cheek and the ventral to the free cheek. Numerous pits with connecting pores pass through this limb from the upper to the under surface. These might be expected to show traces of the separation between the free and the fixed cheek regions. According to Reed,[3] "the hour-glass shaped hollow pillars representing the opposite and communicating pits in the upper and under surfaces are continuous and show no transverse plane of fission." It is of course conceivable that secondary fusion has taken place, but why should there be fusion in the walls of the pits and not along the edge of the cephalon?

The genus *Orometopus*, which possesses well-formed compound eyes and a clearly marked suture of an advanced opisthoparian type, supplies positive and conclusive evidence. This may be best stated in the words of Lake[4]: *Orometopus* "is the earliest genus of the Trinucleidæ and must therefore be looked upon as the primitive form; and the conclusion is inevitable that in the later genera the absence of compound eyes and supposed marginal position of facial sutures are degenerative characters. It is indeed no longer improbable that the ocelli which occur in the middle of the cheeks in some species of *Trinucleus* and *Ampyx* may represent normal eyes, and that the lines which Salter and M'Coy observed running from these ocelli to the margins may be fused facial sutures as they supposed. If this be so the Trinucleidæ can scarcely be included in Beecher's Hypoparia".

Dollo[5] regards *Trinucleus* as a Trilobite adapted for a life spent permanently in the mud. If this was its mode of life it is easy to understand the reduction of the compound eye to such a simple one as that of *Tretaspis* or of the young *Trinucleus*. The loss of the facial suture by the fusion of free with fixed cheeks would produce a more rigid head-shield like that of other Trilobites said to have had a burrowing habit such as *Olenellus* and other Mesonacidæ. The

[1] *Textbook of Palæontology*, Zittel, ed. Eastman, vol. i, p. 713, 1913.
[2] J. Barrande, *Système Silurien*, Trilobites, p. 616.
[3] GEOL. MAG., 1912, p. 347.
[4] Monogr. Palæont. Soc., 1907, p. 45.
[5] *La Paléontologie Ethologique*, Bruxelles, 1910, p. 417.

absence of a facial suture in members of this last-named family is not regarded as barring them from admission to the Opisthoparia, or as justifying their reference to the Hypoparia.

The facts given above together with the evident relationship of *Dionide*[1] to the Trinucleidæ on the one hand and to the Harpedidæ on the other creates a strong presumption in favour of the view that the ocelli of the latter are not of different origin from but are vestiges of compound eyes.[2] If this be so they may mark the position of an opisthoparian type of facial suture which has disappeared under similar influences to those which have acted on *Trinucleus*.[3]

Lake,[4] discussing the systematic position of *Shumardia*, says: "The genus *Shumardia* has by some writers been placed in the family Agnostidæ. Moberg, however, in 1890 pointed out that it presents scarcely any resemblance to *Agnostus*, except in the absence of eyes and facial sutures, and he concluded that it belongs rather to the Olenidæ. At a later date Pompeckj considered it to be most closely related to *Conocoryphe*, while Reed, like Moberg, included it in the Olenidæ." Allowing for the absence of eyes and sutures *Shumardia* resembles *Ellipsocephalus*[5] much more closely than it resembles either *Agnostus*, *Olenus*, or *Conocoryphe*. This comparison is analogous to that of *Trinucleus* with *Orometopus*. The difference in time of appearance of *Shumardia* and *Ellipsocephalus*, however, makes one hesitate to place them near together.

In discussing the Agnostidæ Beecher claims to have found "under favourable conditions of preservation" a distinct plate separated by a suture which "can be compared only with free cheeks".[6] So far as literature is known to me this is the only case in which Beecher actually saw hypoparian free cheeks. It is interesting to note, therefore, that Jaekel,[7] whose material seems to have been exceptionally good, definitely states that sutures are absent. From the fact that some workers seem to have found vestiges of eyes on the cheeks he expresses the opinion that the Agnostidæ are forms in which the eyes have degenerated and the free cheeks have fused with the fixed cheeks. He shows,[8] moreover, that the habit these Trilobites had of shutting themselves up with the edge of the pygidium fitted closely against that of the cephalon necessitates absence of eyes and, correlatively, of facial sutures on the ventral side.

[1] F. R. C. Reed, GEOL. MAG., 1912, p. 202.
[2] Cf. F. R. C. Reed, GEOL. MAG., 1898, p. 446 et seqq.
[3] Some time after this paper was finished Mr. H. H. Thomas kindly called my attention to an article on *Harpes*, by Rudolf Richter, in the *Zoologischer Anzeiger* for December, 1914, a copy of which had reached England. This author has made a very careful study of the minute structure of this genus. He shows that the 'eyespots' consist of biconvex lenses like those of the normal Trilobite eye, and he regards them as vestiges of a once well-developed compound eye. He also shows that the marginal suture cannot be regarded as homologous with the true facial suture.
[4] Monogr. Palæont. Soc., 1907, p. 40.
[5] *Vide infra*.
[6] *Amer. Journ. Sci.*, 1897, p. 183.
[7] Op. cit., p. 387; *vide* also Woods, op. cit., p. 225.
[8] Op. cit., p. 388.

Walcott[1] places his new genus *Mollisonia* near the Agnostidæ, and in describing it refers to indications of eyes and facial sutures on the dorsal side. The course of the sutures is not quite clear either from descriptions or figures, but they seem to conform to the proparian type. The presence of seven free segments gives the deathblow to Jaekel's[2] suggested divisions Miomera and Polymera. At the same time it supplies strong support for his view[3] that the Agnostidæ are highly specialized Trilobites. This specialization in so many respects supplies further support for the hypothesis that their blindness is not primitive, and that the absence of facial sutures is due to fusion and not to the submarginal position of the cheeks.

While the orders Opisthoparia and Proparia correspond to facts easily and clearly observed in nature the same cannot be said of the order Hypoparia. The existence of a hypoparian stage in development and in evolution is open to question. Beecher himself does not seem ever to have actually seen free cheeks on the under side either in young or adult forms except in the doubtful instance of the Agnostidæ. In fact, there seems to be no case known of an adult Trilobite which is undoubtedly hypoparian.

As already seen, Beecher based his conception of a hypoparian stage in evolution largely upon the development of both opisthoparian and proparian forms. He did not, however, give adequate consideration to either the development or the adult structure of that most primitive of all Trilobite families, the Mesonacidæ. Before considering them it is necessary to emphasize the importance and value of one of Beecher's[4] fundamental conceptions, viz. that in the Trilobite organization the facial sutures[5] when present are essentially associated with the eye. Even if the presence of a visual area be denied[6] this conception is still true for the eye-lobe or the homologue of the palpebral lobe.

When Walcott[7] instituted the family Mesonacidæ he described it as being distinguished from the Paradoxidæ by the absence of facial sutures. Beecher[8] states that in *Olenellus* and *Holmia* "false sutures are recognized" which are "evidently real sutures in a condition of symphysis, which often occurs in *Phacops*", etc. This explanation —loss by fusion—was the only one open to him since he believed that even in the earliest stages of evolution sutures were present. Some years later Walcott[9] in discussing the sutures of the family says, "facial sutures are rarely represented even by elevated lines on the exterior surface or depressed lines on the interior surface of the cephalon." He also in defining the family afresh says "facial

[1] Smithsonian Miscellaneous Collections, vol. lvii, p. 195, 1912.
[2] *Vide supra.*
[3] Op. cit., p. 392.
[4] Op. cit., pp. 100, 191.
[5] Cf. J. Barrande, op. cit., pp. 615, 616. Barrande decided that this association of sutures with eyes was not essential. He based his view especially upon the existence of a marginal suture in *Trinucleus.*
[6] Woods, op. cit., p. 233.
[7] Tenth Ann. Rep. U.S.G.S., 1891, p. 635.
[8] Op. cit., p. 191.
[9] Smiths. Misc. Coll., vol. liii, p. 242, 1910.

sutures rudimentary or in a state of synthesis".[1] The rest of his monograph leaves it uncertain as to whether or not he is really using the word rudimentary as opposed to vestigial and synthesis as opposed to symphysis. If the definition be taken at its face value he is evidently leaning towards the point of view of the present writer, viz. that the facial sutures were not necessarily present in primaeval Trilobites and that the Mesonacidæ exhibit the Trilobite organization just when these lines are coming into being. The genus *Nevadia*[2] (Fig. 2*a*), which is one of, if not the most primitive of undoubted Trilobites, and which should therefore approximate to Beecher's hypoparian archetype, has no definitely established facial sutures, and its eyes, like those of all other Mesonacidæ, are situated on the dorsal side far from the margin of the cephalon and close to the glabella—that is to say, it is the reverse of hypoparian in every respect.

Not less decisive is the evidence supplied by the development of the Mesonacidæ. Beecher[3] infers that, because the eye travels over the margin on to the dorsal side during the development of the types he considers, therefore the free cheeks must be wholly ventral. The earliest known stages in the development of *Olenellus* (*Elliptocephalus*) *asaphoides*[4] are quite as early as any of those referred to by Beecher in other types, nevertheless from the very outset the rudiments of the eyes are dorsally situated and are well within the margin of the head-shield. This fact implies that if facial sutures had been present the free cheeks would have been upon the dorsal side. Facial sutures, however, are not present, even though the embryo is so primitive that, unlike any known embryo outside this family, it shows the pleural elements of the fixed cheek region quite distinctly. According to Bernard[5] the facial suture is formed in Trilobites generally along the line which separates the first and second pleuræ.

Walcott[6] has described a new Crustacean genus *Marella* in which he says "the trilobite is foreshadowed". Though so beautifully preserved that even minute details in the structure of the appendages may be discerned there is no mention in his description nor indications in his plates of a facial suture.

Along with *Marella* Walcott[7] also described a primitive Trilobite, *Nathorstia transitans*, which, whilst it is "essentially a Trilobite", yet exhibits characters which link it to the Branchiopods and Merostomes. The position of the eyes and the absence of facial sutures in this genus also bear out the conclusions already indicated above that there was no such stage as the hypoparian in the evolution of Trilobites as a whole. On the contrary, the earliest trilobitic organisms had no facial suture. The Branchiopods and the Merostomes approach more closely to these than do any other animals. In the former there are no traces of sutures. In some of the latter

[1] Smiths. Misc. Coll., vol. liii, p. 236, 1910.
[2] Ibid., p. 257.
[3] Op. cit., p. 100.
[4] Ford, *Amer. Journ. Sci.*, 1877, 1881; Walcott, op. cit., 1891, pl. lxxxviii; Bull. U.S.G.S., No. 30, pl. xvii, 1886.
[5] Q.J.G.S., 1894, p. 419.
[6] Op. cit., 1912, p. 192.
[7] Op. cit., p. 194.

a posterior facial suture such as has been seen apparently in some Mesonacidæ is present, but no well-established and clearly defined line such as characterizes the majority of Trilobites occurs.

For the reception of Trilobites and Trilobite-like organisms in which the absence of facial sutures is primary the Order Protoparia may be instituted. From this protoparian stock there arose independently, as will be seen, several widely different types with free cheeks. The position in which the suture appeared in the earliest representatives of each of these types depended upon the position of the eye, whether it was near the glabella, or near the margin, or, conceivably in some cases, on the ventral side.

The Interrelationships of the Pro- and Opisthoparia.

The predominance of Opisthoparia in the Cambrian and of the Proparia in later rocks suggests that the latter descended from the former. This is apparently supported by the existence of the families Calymmenidæ and Homalonotidæ, in which the suture cuts the margin at the genal angle and thus seems to furnish a transition from one to the other.

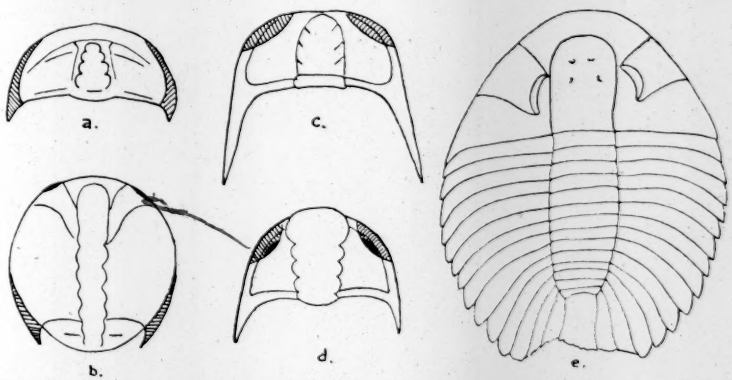

Fig. 1.—Diagrams to illustrate differences in mode of origin of free cheeks of Opisthoparia and Proparia. *a*. Head-shield of *Conocoryphe* (from Beecher); *b*. metaprotaspis of *Ptychoparia kingi* (from Beecher, *Amer. Geol.*, 1895, p. 171); *c*. head-shield of *Anacheirurus* (*Cheirurus*) *frederici* (reconstructed after Salter, Mon. Pal. Soc., pl. v, fig. 18); *d*. head-shield of young *Dalmanites* (from Beecher); *e*. *Burlingia* (after Walcott).

The discovery of *Burlingia*[1] (Fig. 1*e*) as early as the Middle Cambrian throws doubt on this view of the interrelationships of the two orders. This form is in many respects as primitive as the Mesonacidæ and yet is as typically proparian as the most specialized of the Cheiruridæ. On the other hand, the families Calymmenidæ and Homalonotidæ do not appear before the Tremadocian.

If Proparia descended from Opisthoparia evidence should be forthcoming from their development. But such evidence is altogether lacking. The development of the free cheek follows quite different

[1] C. D. Walcott, Smiths. Misc. Coll., vol. liii, p. 14, 1908.

lines in the two orders (Figs. 1*b*, *d*). In Opisthoparia the suture becomes visible for the first time at the *postero-lateral* margin of the head-shield; in Proparia, on the contrary, it appears at the *antero-lateral* margin. This difference is exhibited in adult life also by the lowliest members of the two orders; compare, for example, *Conocoryphe* and *Anacheirurus* (Figs. 1*a*, *c*). The opisthoparian and proparian conditions are therefore differentially or mutually exclusive and have arisen independently. As will be shown later, this conclusion receives confirmation from the existence of evidence that the opisthoparian condition has been evolved independently at least twice within the limits of the order Opisthoparia.

The Calymmenidæ and Homalonotidæ.

As long ago as 1898 Pompeckj[1] traced the descent of the Calymmenidæ through *Pharostoma* to *Bavarilla*; *Pharostoma* has narrow marginal cheeks of the opisthoparian type and *Bavarilla* is one of the Olenidæ.[2] He likewise traced the Homalonotidæ back to the olenid genus *Neseuretus*. In other Olenidæ,[2] e.g. *Triarthrus*, the facial suture cuts the margin at the genal angle. It is evident, therefore, that among some of the olenid Opisthoparia one tendency of specialization is the shifting of the post-ocular facial suture towards the genal angle. This tendency develops most rapidly in, and becomes the dominant peculiarity of, the Calymmenidæ and the Homalonotidæ.

Gurich grasped the importance of this peculiarity and formed a group, the Gonatoparia, to include those families which show it. This group has not the same taxonomic value as the two orders; it might, however, be regarded as a section, the Calymmenina, of that large and unwieldy assemblage the Opisthoparia.

The error in Gurich's Classification.

A glance at a system of classification should reveal first the main lines of descent and after that the progressive stages along each of those lines. For defining lines of descent differential characters are the most reliable, hence the solidity of two of Beecher's orders. The foundation mistake made by Gurich is that his main divisions are based upon progressive characters, viz. differences in the number of free segments and in the size of the pygidium. Beecher's order Hypoparia exhibits the same weakness. The institution of an order Protoparia is open to the same criticism.

It is beyond question that the earliest ancestors of the Trilobites and indeed of all Arthropods possessed an annelidan type of segmentation.[3] In all Arthropods this has been masked in the anterior part of the body by the fusion of segments. This process of cephalization reaches its acme in the crab-like Crustacea. It is characteristic of the Trilobite organization that it also exhibits a strong tendency for a similar fusion to take place at the posterior end of the body. Gurich emphasizes the importance of this tendency by unconsciously

[1] *Neues Jahrb.*, 1898, p. 187.
[2] Strictly that portion of Olenidæ relegated later to the Ptychoparidæ.
[3] Cf. H. M. Bernard, Q.J.G.S., 1894, 1895.

making it the basis of his classification, and the names of some of his sub-orders may be usefully adapted for describing the stages in this process of caudalization.

The earliest and most primitive stage is one in which the pygidium consists of a telson or of a telson plus only two or three segments—this may be called the *micropygous* stage. This passes into the *heteropygous* stage, in which the pygidium includes a greater number of segments, but is distinctly smaller than the cephalon. In the final or *isopygous* stage the pygidium is approximately equal to or even larger than the cephalon.

Some or all of these stages may be represented in any genetic series of Trilobites. The use of the number of free segments and the size of the pygidium as the definitive characters of orders or sub-orders results in the bringing together of forms which belong to quite different lines of descent, e.g. Asaphidæ and Phacopidæ,[1] and separates others which are closely allied, e.g. Arethusinidæ and Proetidæ.[1]

Suggested Subdivision of the Opisthopakia.

The order Opisthoparia now contains such a great number of families that some division into sub-orders is rendered necessary. One distinct section, the Calymmenina, has been already recognized (p. 494). The remaining families must now be studied with a view to detecting, if possible, other equally natural groups within this order.

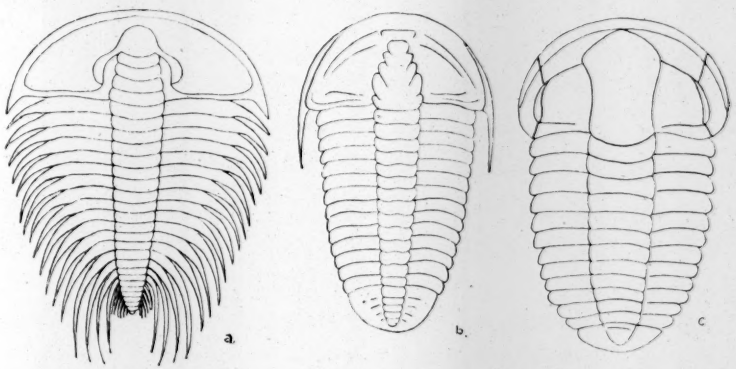

Fig. 2.—Types of Lower Cambrian Trilobites. *a. Nevadia* (after Walcott, 1910, pl. xxiii); *b. Conocoryphe* (*Conocephalites*) *sulzeri* (after Bronn, Klass, Ord., Bd. v, Arthropods, pl. xlv); *c. Ellipsocephalus* (after Barrande).

Already in the Lower Cambrian the genera *Nevadia*.[2] *Conocoryphe*,[3] and *Ellipsocephalus* exhibit distinct types. Though in one or two respects each is specialized, in the general sum of their characters they are each more primitive than any other allied genera.

[1] *Vide* p. 488.
[2] C. D. Walcott, Smiths. Misc. Coll., vol. liii, p. 256, 1910.
[3] *Conocephalites sulzeri*, Schlot.

In the head-shield of *Nevadia* the glabella diminishes anteriorly, and is divided by complete transverse furrows into five segments, of which the first is longer than the others, and sends off lateral stout eye-lobes which probably bear a visual area[1] externally and distally. In *Conocoryphe* the glabella is almost equally primitive, but its anterior segment is small and its furrows oblique and not continuous across. The absence of eyes is probably secondary.[2] In *Ellipsocephalus* the glabella has already attained a high degree of specialization, for it is quadrate in outline and may have all its furrows smoothed away. It possesses eyelines and elongated eyes, both of which are primitive characters.

In *Nevadia* there is no facial suture, but its potential position (Figs. 2*a* and 3*a*) is marked by the eye. From this it will be seen that the free cheek region of *Nevadia* is of great breadth, whilst the fixed cheek is particularly narrow. In *Conocoryphe* (Fig. 2*b*) and *Ellipsocephalus* (Fig. 2*c*) these relative proportions are reversed, for the free cheek is narrow and marginal whilst the fixed cheek is broad.

The fixed cheek largely represents the pleural portions of the hind segments of the glabella. Its insignificance in the one genus and its great size in the other genera accord with the morphological characteristics of the trunk segments.

Bernard[3] considers that in the evolution of Arthropods from an annelid ancestor pleuræ appeared first on the head segments, and that the early Arachnids and Trilobites specialized by "the continuation of the original head pleuræ along the whole length of the body". In *Nevadia* (Fig. 2*a*) this specialization has not advanced so far as in *Conocoryphe* and *Ellipsocephalus*. Leaving the pleural spine out of account the pleural lobes of the first few trunk segments of *Nevadia* are not so imposing as in the other two genera. They then diminish in size posteriorly and finally disappear, so that the hinder segments consist of axis only. In other genera (Figs. 2*b*, *c*) the pleural lobes are well developed even in the pygidium.

(*To be concluded in our next Number.*)

III.—On some new Uniserial Cretaceous Cheilostome Polyzoa.

By W. D. Lang, M.A., F.G.S.

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(PLATE XVII.)

I. Rhammatopora,[4] new genus.

In 1890 Vine described *Membranipora gaultina*,[5] a uniserial Cheilostome from the Cambridge Gault. A peculiarity of this species was 'a puckering' or 'folding-in of the wall below the area'

[1] *Vide* Walcott on *Olenellus gilberti*, in Smiths. Misc. Coll., vol. liii, p. 327, 1910. The discovery of the presence of a visual area in *Olenellus gilberti* is against Wood's suggestion (op. cit., p. 232) that the eye-like lobe of *Olenellus* "is really of the nature of a pleura".

[2] *Nevadia*, *Burlingia*, *Marella*, *Nathorstia*, are all more primitive than *Conocoryphe*, and yet they all possess well-formed eyes. Again, secondary loss of eyes is now definitely established in some families, e.g. Trinucleidæ.

[3] Q.J.G.S., 1895, p. 359.

[4] τό ῥάμμα, 'a seam.'

[5] Vine, 1890, Quart. Journ. Geol. Soc., vol. xlvi, pp. 484, 461.

shown by Vine in his figure of the type-specimen.[1] Unfortunately this specimen cannot be found; but a well-preserved paratype specimen (from the same horizon and locality) exhibits the same structure and shows that this is due to the collapse of the extra-terminal front wall along a median line proximal to the aperture. Other zoœcia of the same specimen show the extra-terminal front wall entire and a thin median seam—or *rhamma*—running proximally from the aperture. The rhamma appears in some instances as a ridge and in others as a depression; in some zoœcia it is not apparent; and when visible is extremely fine. In many cases the front wall is broken along it (as in Vine's figure) and thus the rhamma probably indicates a line of weakness. It is suggested that the rhamma is a ridge bounded by two furrows and that the front wall is thicker at the ridge and thinner in the furrows. The rhamma, then, would easily be broken off, and in such specimens a depression would appear in its place; and a thin groove on each side would constitute a general line of weakness which would account for the frequent breaking down of the front wall. Owing to the extreme fineness of the structure it cannot be definitely stated that that is the case. Vine further records *Membranipora gaultina* from the Red Chalk of Hunstanton[2] and from the Chalk Marl of Cambridge.[3] Specimens of the former horizon only are in his collection, but similar forms from the latter horizon have been obtained by washing by the late Mr. F. Möckler and are in the British Museum. In each case the rhamma is shown, though the specimens show differences from each other and from the Gault form. Finally Mantell[4] figures and describes from the Lower Greensand a uniserial Cheilostome possessing a rhamma and obviously related to the Albian and Cenomanian forms. These then may be grouped in a new genus *Rhammatopora*, with the following diagnosis.

Diagnosis. Incrusting, uniserial, Cheilostome Polyzoa with bilateral branching;[5] zoœcia monomorphic, divided into a proximal caudal and distal capitular portion; termen[5] beaded; extra-terminal front wall[5] well developed proximally and provided with a median seam or rhamma which also appears to mark a line of weakness since the extra-terminal front wall is often crushed in along this line; intra-terminal front wall[5] represented by a narrow bevel, tending to become broader proximally.

Genotype. *Membranipora gaultina*, Vine.

Distribution in time. Aptian to Cenomanian.

Remarks. Of the three genera into which the species of *Rhammatopora* have been placed by various authors, *Crisia* is a Cyclostome Polyzoan, *Membranipora* is multiserial and *Hippothoa* has a completely calcareous intra-terminal front wall; none possesses a rhamma.

[1] Vine, 1892, Proc. Yorks. Geol. Poly. Soc., new series, vol. xii, part 2, pl. vi, fig. 15.

[2] Vine, 1890, *loc. cit.*

[3] Vine, 1890, *op. cit.*, p. 461.

[4] Mantell, 1844, "Medals of Creation," p. 285, pl. lxiv, figs. 3, 10, 10*b*.

[5] For these terms, see Lang, 1914, GEOL. MAG., Dec. VI, Vol. I, p. 6.

Key to the genus *Rhammatopora*.

A. Zoœcia tapering somewhat distally as well as proximally; proximal end of capitulum bounded by well-curved lines 1. *R. johnstoniana* (Mantell).

B. Zoœcia blunt distally and tapering proximally.
1. Outline of proximal end of capitulum bounded by hardly-curved lines; aperture elliptical. 2. *R. vinei*, n.sp.
2. Outline of proximal end of capitulum bounded by well-curved lines.
a. Extra-terminal front wall small laterally; aperture oval to ovate . . . 3. *R. gaultina* (Vine).
b. Extra-terminal front wall well-developed laterally; aperture ovate to elliptical . 4. *R. pembrokiae*, n.sp.

RHAMMATOPORA JOHNSTONIANA (Mantell).

Synonymy.

Crisia Johnstoniana; Mantell, 1844, "Medals of Creation," 1st edition, p. 285, pl. lxiv, figs. 3, 10, and 10*b*; and 1854, *op. cit.*, 2nd edition, p. 269, pl. lxxxix, figs. 3, 10, 10*b*.

non Hippothoa Johnstoni (Mant.); Morris, 1854, "A Catalogue of British Fossils," 2nd edition, p. 125; Upper Chalk; Kent, Sussex. [? = *Herpetopora anglica*].

non = *Membranipora dispersa*, Hag.; as stated by Vine, 1893, "Report . . . on Cretaceous Polyzoa," Rep. Brit. Assoc., Edinburgh, 1892, p. 316.

Revised diagnosis. *Rhammatopora* in which the angle of branching is small, 45° or less; the zoœcia taper somewhat distally as well as proximally; the capitulum is bounded proximally by well-curved lines; and the aperture is elliptical.

Distribution. Aptian, Lower Greensand, Shanklin Sand; Maidstone, Kent.

Remarks. Mantell's figures only are available for the interpretation of this species, but the generic and specific characters can easily be seen in them. The branching appears to be somewhat irregular; how far this was so can be settled only if the type is found. Compare the similar case of the figured specimen of *R. gaultina*.

RHAMMATOPORA VINEI, n.sp. Pl. XVII, fig. 1.

Synonymy.

Membranipora gaultina, sp. nov.; Vine, 1890, Quart. Journ. Geol. Soc., vol. xlvi, pp. 484, 461, pl. xix, figs. 13*a–d*; Red Chalk; Hunstanton.

non Membranipora gaultina, sp. nov.; Vine, 1890, *loc. cit.*; Gault; Cambridge. [= *Rhammatopora gaultina* (Vine) q.v.].

non Membranipora gaultina, sp. nov.; Vine, 1890, *op. cit.*, p. 461; Chalk Marl. [Probably = *Rhammatopora pembrokiae*, q.v.].

Membranipora gaultina, Vine; Vine, 1891, Proc. Yorks. Geol. Poly. Soc., new series, vol. xi, part iii, pp. 385, 396; Red Chalk, Hunstanton.

non Membranipora gaultina, Vine; Vine, 1891, *loc. cit.*; Gault; Cambridge. [= *Rhammatopora gaultina* (Vine), q.v.].

Membranipora gaultina, var., Vine: Vine, 1891, Rep. Brit. Assoc., Leeds, 1890, p. 395; Red Chalk; Hunstanton.

Membranipora gaultina, Vine; Vine, 1892, Proc. Yorks. Geol. Poly. Soc., new series, vol. xii, part ii, p. 155; Red Chalk; Hunstanton.

non Membranipora gaultina, Vine; Vine, 1892, *op. cit.*, pp. 154–5, pl. vi, fig. 15; Gault; Barnwell, Cambridge. [= *Rhammatopora gaultina* (Vine), q.v.].

Membranipora gaultina, Vine; Vine, 1893, Rep. Brit. Assoc., Edinburgh, 1892, p. 335; Red Chalk; Hunstanton.

Diagnosis. *Rhammatopora* in which the angle of branching is wide —more than 45°; the zoœcia are blunt distally; the capitulum is bounded proximally by nearly straight lines; and the apertures are elliptical.

Type-specimen. British Museum specimen D 2051; Vine's figured specimen of *Membramipora gaultina*, 1890, *op. cit.*, Pl. xix, figs. 13*a–b*; T. Jesson Coll.

Distribution. Albian, Red Chalk; Hunstanton, Norfolk.

Remarks. Although in his first description of *Membranipora gaultina* Vine figured this species, it is clear from this description that he intended the Cambridge Gault specimen for the type and included in the species the Red Chalk and Chalk Marl forms.

RHAMMATOPORA GAULTINA (Vine). Pl. XVII, fig. 2.

Synonymy.

Membranipora gaultina, sp. nov.; Vine, 1890, Quart. Journ. Geol. Soc., vol. xlvi, pp. 484, 461; Gault; Cambridge.

non Membranipora gaultina, sp. nov.; Vine, 1890, *loc. cit.*, and pl. xix, figs. 13*a–d*; Red Chalk; Hunstanton. [= *Rhammatopora vinei*, q.v.].

non Membranipora gaultina, sp. nov.; Vine, 1890, *op. cit.*, p. 461; Chalk Marl. [Probably = *Rhammatopora pembrokiae*, q.v.].

Membranipora gaultina, Vine; Vine, 1891, Proc. Yorks. Geol. Poly. Soc., new series, vol. xi, part iii, pp. 385, 396; Gault; Cambridge.

non Membranipora gaultina, Vine; Vine, 1891, *loc. cit.*; Red Chalk; Hunstanton. [= *Rhammatopora vinei*, q.v.].

non Membranipora gaultina, var., Vine; Vine, 1891, Rep. Brit. Assoc., Leeds, 1890, p. 395; Red Chalk; Hunstanton. [*Rhammatopora vinei*, q.v.].

Membranipora gaultina, Vine; Vine, 1892, Proc. Yorks. Geol. Poly. Soc., new series, vol. xii, part ii, pp. 154–5, pl. vi, fig. 15; Gault; Barnwell, Cambridge.

non Membranipora gaultina, Vine; Vine, 1892, *op. cit.*, p. 155; Red Chalk; Hunstanton. [= *Rhammatopora vinei*, q.v.].

non Membranipora gaultina, Vine; Vine, 1893, Rep. Brit. Assoc., Edinburgh, 1892, p. 335; Red Chalk; Hunstanton. [= *Rhammatopora vinei*, q.v.].

Revised diagnosis. *Rhammatopora* in which the angle of branching is wide, more than 45°; the zoœcia are blunt distally; the capitulum is bounded proximally by well-curved lines; the extra-terminal front wall is small laterally; and the aperture is oval to ovate.

Type-specimen. Vine's type cannot be found; but in his description Vine mentions having by him specimens of this species from the Gault of Cambridge and belonging to Mr. Jesson. British Museum specimen D. 2062 of the Jesson collection and labelled "*Membranipora gaultina*, Cambridge, Gault, in situ" is therefore in all probability a paratype, and in the absence of Vine's examples may be taken as the type specimen.

Distribution. Albian, Gault; Cambridge.

RHAMMATOPORA PEMBROKIAE,[1] n.sp. Pl. XVII, figs. 3 & 4.

Synonymy.

Probably Membranipora gaultina, sp. nov.; Vine, 1890, Quart. Journ. Geol. Soc., vol. xlvi, p. 461; Chalk Marl.

non Membranipora gaultina, sp. nov.; Vine, 1890, *op. cit.*, pp. 484, 461, pl. xix, figs. 13*a–d*; Gault, Cambridge; Red Chalk, Hunstanton.

[1] In memory of Mary de Valence, Countess of Pembroke, foundress of Pembroke College, Cambridge.

Diagnosis. *Rhammatopora* in which the angle of branching is more than 45°; the zoœcia are blunt distally and taper proximally; the capitulum is bounded proximally by well-curved lines; extra-terminal front wall comparatively wide laterally; rhamma feebly developed, often not visible; aperture ovate to elliptical.

Type-specimen. British Museum specimen D. 22987.

Distribution. Cenomanian, Chalk Marl; N.E. of Cambridge. F. Möckler Coll.

Remarks. The feeble development of the rhamma suggests that this structure disappears during evolution and thus *Rhammatopora* gives rise to *Allantopora*.

II. Charixa,[1] new genus.

In *Rhammatopora* the angle of branching generally is wide, and the caudal portions of the zoœcia, though shorter at the beginnings of each branch (each branch recapitulates a former short-caudal condition), quickly resume their normal length. The resulting zoarium is thus always uniserial both in design and in fact. A form possessing a rhamma and generally resembling *Rhammatopora* has been found in the Albian at Charmouth, Dorset; but the branching is peculiar, and, though strictly bilateral, does not on the whole produce a uniserial zoarium. The caudæ are never very long, and practically absent at branching; moreover the angle of branching is small, as in *Rhammatopora johnstoniana* (Mantell), and the new branches freely branch again on the bilateral method. The zoaria, therefore, though uniserial in principle, often contain patches which are actually multiserial. Two other characters of this genus are the rapid increase in size, so that the daughter zoœcia are often much larger than their parents; and the habit (shared with other uniserial Cretaceous Cheilostomes, but very marked in this form) of eroding the shell it incrusts. In the type-specimen a form of rejuvenescence occurs. In the case of two large zoœcia in a multiserial patch, the terminal buds are small zoœcia with fairly long caudæ and a rather wide angle of branching. The long caudæ are in keeping with a continuation of the branch; but the sudden smallness of size of the zoœcia and widening of the angle of divergence of the branch are a recapitulation of (presumably) earlier conditions in characters in which the lateral branches (which normally recapitulate a short caudal stage) do not recapitulate. The resulting appearance is of new zoaria starting from points on an old zoarium; so it is described here as a rejuvenescence. *Charixa* has been found incrusting *Hoplites splendens* (James Sowerby) in the Albian, zone of *Hoplites interruptus*, and on *Gervillia forbesiana*, d'Orbigny, and *Exogyra conica* (James Sowerby) in the Albian, zone of *Mortoniceras rostratum*, Cowstone horizon, at Black Ven, Charmouth. Also in the Gault of Dunton Green, N. of Sevenoaks, Kent (B.M. specimens D. 23021–4 and a specimen kindly lent me by Mr. A. G. Davis, Hon. Curator of the Croydon Natural History and Scientific Society).

[1] *Carixa*, an old name of Charmouth (the type locality; see Roberts, 1823, "The history of Lyme Regis, Dorset," p. 220), probably = '*Char, isca*' (altered to '*ixa*' as in Exe, Axe, &c.), i.e. "Char river". I have therefore altered the spelling to *Charixa* that this generic name may better recall the locality.

Diagnosis. Incrusting Cheilostome Polyzoa with bilateral branching, and typically uniserial, though actually multiserial patches often occur owing to the smallness of the angle of branching, the frequency of branching and the shortness or absence of caudæ in the first individuals of a branch; zoœcia monomorphic, divided into a distal capitular and a proximal caudal portion which may, however, be very short or even absent; termen beaded; extra-terminal front wall well developed proximally and provided with a rhamma; intra-terminal front wall represented by a narrow bevel tending to become wider proximally.

Genotype. *Charixa vennensis*, n.sp.

Distribution in time. Albian.

CHARIXA VENNENSIS,[1] n.sp. Pl. XVII, figs. 5 & 6.

Diagnosis. As for the genus *Charixa*.

Type-specimen. British Museum specimen D. 22950; Cowstones; Charmouth; Coll. W. D. Lang.

Distribution. Albian, zone of *Hoplites interruptus*, Bed 3, and zone of *Mortoniceras rostratum*, lower part, Cowstone horizon; Black Ven, Charmouth, Dorset.

III. PYRIPORA, d'Orbigny.[2]

In 1914[3] in a paper dealing with some uniserial Cretaceous Cheilostomes, I wrongly stated that d'Orbigny founded the genus *Pyripora* on three genosyntypes in his "Prodrome de Paléontologie Stratigraphique", in 1850. As a matter of fact he had already founded this genus in 1849,[2] selecting as his genotype *Criserpia pyriformis* of Michelin,[4] and I take this opportunity of acknowledging my error. *Criserpia* was founded by Edwards[5] for a Cyclostome Polyzoan, and *Pyripora*, therefore, stands as the genus for Michelin's species, which, though not a Cyclostome, is not easily interpreted in detail from Michelin's figure. As far as can be seen from the figure the termen is not beaded and there are no avicularia. It differs from *Herpetopora*, therefore, chiefly in the shortness or absence of the caudæ in the angle of branching and probably in the method of branching. Only a provisional diagnosis, therefore, is given.

Provisional diagnosis. Incrusting uniserial or pauciserial Cheilostome Polyzoa with unilateral[6] (and ? sometimes bilateral) branching; zoœcia monomorphic with very short caudæ or without caudæ; termen plain; extra-terminal front wall well developed proximally, with no rhamma; intra-terminal front wall represented by a narrow bevel, tending to become broader proximally.

Genotype. *Criserpia pyriformis*, Michelin.[4]

Distribution in time. Miocene, Falunian.

[1] From Black Ven, the cliff from which the type-specimen came.

[2] d'Orbigny, 1849, Revue et Magasin de Zoologie, 2nd series, vol. i, p. 499.

[3] Lang, 1914, GEOL. MAG., Dec. VI, Vol. I, p. 436.

[4] Michelin, 1848, Iconographie Zoophytologique, p. 332, pl. lxxix, fig. 6.

[5] Edwards, 1838, Annales des Sciences Naturelles, series ii, Zoologie, vol. ix, pp. 208, 238, pl. xvi, fig. 4; *genotype C. Michelinii.*

[6] i.e. with a distal bud and one lateral bud.

IV. Mystriopora,[1] new genus.

In 1846[2] Reuss described two uniserial Cheilostomes from the Cenomanian of Bohemia. One of these, *Escharina dispersa*, Reuss, has been already dealt with and renamed *Dacryopora reussi*.[3] The other, *Escharina perforata*, Reuss, apparently agrees generically with a form washed from the Chalk Marl of Cambridge by the late Mr. F. Möckler. It cannot remain in the genus *Escharina*[4] which was founded by Edwards for twenty-eight recent species differing altogether from the form under consideration. It is therefore here placed provisionally with the Chalk Marl specimen from Cambridge, which is the genotype of a new genus, *Mystriopora*.

Diagnosis. Incrusting, pauciserial Cheilostome Polyzoa with early uniserial stages, and with bilateral to unilateral branching; zoœcia dimorphic; normal zoœcia oval or slightly pyriform with very short caudæ or with no caudæ; termen with spines; extra-terminal front wall well developed proximally; intra-terminal front wall a very small bevel; aperture oval; avicularia small, often a pair placed laterally and distally to each aperture.

Genotype. *Mystriopora möckleri*, n.sp.

Distribution. Cenomanian.

Key to the genus *Mystriopora*.

A. Avicularia rare, without sharp points; zoarium largely uniserial. 1. *M. perforata* (Reuss).

B. Avicularia frequent, sharply pointed; zoarium largely pauciserial. 2. *M. möckleri*, n.sp.

Mystriopora möckleri, n.sp. Pl. XVII, fig. 7.

Diagnosis. *Mystriopora* in which the pauciserial habit is soon attained and the avicularia are numerous and sharply pointed.

Type-specimen. British Museum specimen D. 21670. F. Möckler Coll.

Distribution. Cenomanian, base of Chalk Marl, N.E. of Cambridge.

V. Distelopora,[5] new genus.

Among the material washed by the late Mr. F. Möckler from the Chalk Marl of Cambridge are several specimens of an incrusting Cheilostome, uniserial in its early stages and differing from previously described Cretaceous forms; the following is a diagnosis:

Diagnosis. Incrusting multiserial Cheilostome Polyzoa with unilateral branching, but with early uniserial stages with bilateral branching; zoœcia monomorphic, oval with no caudæ; termen with eight spines of which the proximal pair are widely separate from the distal three pairs and much larger than them; extra-terminal front wall wide laterally and proximally; intra-terminal front wall laterally and proximally is a wide bevel or narrow lamina; aperture ovate to elliptical, somewhat constricted laterally.

[1] *τό μυστρίον*, '*a spoon*'; the normal zoœcia resemble the bowl of a spoon.
[2] Reuss, 1846, Verstein. bohm. kreideform; part 2, pp. 67–8.
[3] Lang, 1914, *op. cit.*, p. 443.
[4] Edwards in Lamarck, 1836, "Hist. Nat. Animaux sans Vertèbres," 2nd edition, vol. ii, p. 230.
[5] δι- prefix meaning '*two*' and *ἡ στήλη* '*a post*'.

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RHAMMATOPORA, CHARINA, MYSTRIOPORA AND DISTELOPORA

Genotype. *Distelopora bipilata*, n.sp.
Distribution. Cenomanian.

Distelopora bipilata,[1] n.sp. Pl. XVII, figs. 8 & 9.

Diagnosis. As for the genus.
Type-specimen. British Museum specimen D. 23019. F. Möckler Coll.
Distribution. Cenomanian, Chalk Marl, 10–20 feet from base; N.E. of Cambridge.

VI. A Key to the Cretaceous Uniserial Cheilostome Polyzoa.

In two former papers[2] uniserial Cretaceous Cheilostomes have been dealt with, and for convenience in determination a synopsis of the different genera described is here given.

A. Calcareous portion of intra-terminal front wall confined to a narrow bevel.
- I. No avicularia present.
  - a. Termen plain—no rhamma.
    1. Uniserial with bilateral branching with wide angle of divergence . . . . . *Herpetopora*. Cenomanian–Danian.
    2. Pauciserial or uniserial with unilateral branching with small angle of divergence . . . . *Pyripora*. Miocene.
  - b. Termen with beads or spines.
    1. No rhamma . . . . . *Allantopora*. Danian.
    2. A rhamma present.
       - α. Branching with wide angle of divergence; caudæ long . . . . . *Rhammatopora*. Aptian to Cenomanian.
       - β. Branching with small angle of divergence; caudæ short or absent . . . . . *Charixa*. Albian.
- II. With avicularia. Termen with spines or beads.
  1. Uniserial with bilateral branching throughout *Marssonopora*. Upper Senonian.
  2. Uniserial condition with bilateral branching only in early zoarial stages . . . . . *Mystriopora*. Cenomanian.

B. Calcareous portion of intra-terminal front wall consisting of a very broad bevel or lamina; no avicularia; later zoarial stages multiserial with unilateral branching; proximal terminal spines very large . . . . . *Distelopora*. Cenomanian.

C. Intra-terminal front wall entirely calcareous. . . *Dacryopora*. ? Cenomanian to Senonian.

EXPLANATION OF PLATE XVII.

Fig.

1. *Rhammatopora vinei*. Two zoœcia of the type-specimen (the specimen figured by Vine as *Membranipora gaultina*, Quart. Journ. Geol. Soc., Vol. xlvi, Pl. xix, figs. 13 *a–b*). × about 25 diameters. British Museum specimen No. D. 2051. Albian, Red Chalk. Hunstanton, Norfolk. T. Jesson Collection.
2. *Rhammatopora gaultina* (Vine). Two zoœcia and the cauda of a third which has collapsed along the line of the rhamma. This structure is

[1] bi- prefix meaning '*two*' and pila '*a pillar*'.
[2] Lang, 1914, Geol. Mag., Dec. VI, Vol. I, pp. 5 and 436.

clearly shown in one of the perfect zoœcia but is hardly visible in the other. What may be the remains of a fourth bud occurs on the right-hand side of the zoœcium of the main branch (cf. Vine's figure of his type-specimen, Proc. Yorks. Geol. Poly. Soc., new series, Vol. xii, Pl. vi, fig. 15). × about 27 diameters. British Museum specimen No. D. 2062. Albian, Gault. Cambridge. T. Jesson Collection.

3. *Rhammatopora pembrokiæ.* Three zoœcia of the type-specimen, in one of which the intra-terminal front wall has collapsed along the line of the rhamma. The rhamma is not clearly shown in the other two zoœcia. × about 29 diameters. Part of British Museum specimen No. D. 22987. Cenomanian, Chalk Marl. Cambridge. F. Möckler Collection.
4. *Rhammatopora pembrokiæ.* A single zoœcium of another specimen showing the rhamma. × about 26 diameters. British Museum specimen No. D. 22986. Cenomanian, Chalk Marl. Cambridge. F. Möckler Collection.
5. *Charixa vennensis.* Several zoœcia of the type-specimen showing the method of branching and in one place an example of rejuvenescence. × about 29 diameters. British Museum specimen No. D. 22950. Albian, Upper Gault, Cowstone horizon. Black Ven, Charmouth, Dorset. Collected by W. D. Lang.
6. *Charixa vennensis.* A renewed zoœcium of another specimen, showing the rhamma. × about 35 diameters. British Museum specimen No. D. 22935. Albian, Upper Gault, Cowstone horizon. Black Ven, Charmouth, Dorset. Collected by W. D. Lang.
7. *Mystriopora möckleri.* Several zoœcia of the type-specimen showing the early uniserial stage with bilateral branching passing into a pauciserial stage with unilateral branching. × about 26 diameters. British Museum specimen No. D. 21670. Cenomanian, Chalk Marl. Cambridge. F. Möckler Collection.
8. *Distelopora bipilata.* Several zoœcia of the type-specimen showing the early uniserial stage with bilateral branching passing into a multiserial condition with unilateral branching. × about 28 diameters. British Museum specimen No. D. 23019. Cenomanian, Chalk Marl. Cambridge. F. Möckler Collection.
9. *Distelopora bipilata.* A single zoœcium of another specimen, more adult than those of fig. 8, showing very clearly the number and nature of the spines and the very wide intra-terminal front wall. × about 30 diameters. British Museum specimen No. D. 21883. Cenomanian, Chalk Marl, Cambridge. F. Möckler Collection.

IV.—The Ice Age in England.

By Dr. Nils Olof Holst (late of the Geological Survey of Sweden).

(*Concluded from the October Number, p. 444.*)

In the preceding paragraphs it has been shown that, after the inland ice had attained its southernmost limit and had spent its force, there commenced in Southern England the last of many stages of land depression. This carried with it a complete reversal: the temperature was raised, the periphery of the inland ice melted, its pressure was lessened, and a rapid rise of the land—the Mousterian elevation—introduced a great rise, to which the origin of the submerged forests bears witness. Nevertheless, the greatest part of the land depression persisted even after Mousterian time, and this explains the continuance of the melting and its increased rapidity, as well as the rapid northward withdrawal of the inland ice, which we shall soon consider.

It is well known to archæologists that after the Mousterian stage, in other words, after the maximum of glaciation, which is usually described as a moist period, that is to say, not too intensely cold, the climate during the Aurignacian and Solutrian stages began to improve. This no doubt led to a rapid and considerable melting of the inland ice, but found no further expression than that it was still possible for the northern animals to remain in Middle Europe. During the Magdalenian period, on the contrary, the winter of the Ice Age returned, now in increased strength, killing off certain pre-glacial animals which had succeeded in living through all the preceding stages of the Ice Age, e.g. the mammoth and the cave bear, and drove others away from Northern Europe, e.g. the lion, the hyæna, and the horse. From this the conclusion may be drawn that during the Magdalenian period the cold was stronger than during the whole of the preceding Ice Age. It was in the Magdalenian that the reindeer first began to thrive in Middle Europe, and indeed became so numerous that the whole of the Magdalenian can with good reason be called 'l'âge du renne'. Another result of the increased cold is the new advance of the inland ice. This resulted in a so-called zone of oscillation.

The milder climate of that part of the Ice Age which is older than the Magdalenian has often evoked the doubt whether the Ice Age really had a cold climate. In 1907 R. F. Scharff [1] reverted to this question, and taking his stand on observations made by himself and others, such as Saporta and Tscherski, expressed the opinion that the climate of the Ice Age was not colder than that at present obtaining. "Saporta," he said, "contended, indeed, from a study of the plants, that the climate of Europe during the glacial period, *at some distance from the glaciers*, was milder, though more humid, than it is now." This is certainly correct if the words here italicized by me be given their due weight, and if the opinion is confined to those warmer phases of the Ice Age to whose rather temperate climate both fauna and flora bear clear witness.

As regards the fauna, it is enough to refer to Déchelette's [2] account of the mammals during the Aurignacian and Solutrian stages. The concordant palæobotanical researches of Carl Weber and N. Hartz have made known the flora in the most southerly districts where the ice first melted in North Germany and Jutland; and this shows, with equal or perhaps even greater clearness than the fauna, that the temperature cannot have been low during this period of melting. But the exhaustive researches of Weber on the peat bogs of Honerdingen near Walsrode, about 50 kilometres north of Hanover,[3] have shown that the peat flora during the warmest time of the formation of the peat indicates a temperature higher than that now obtaining there, "yet not greater than that now obtaining in Thuringia," the middle point of which lies at about two degrees of

[1] R. F. Scharff, 1907. *European Animals*, London, pp. 45–7.

[2] J. Déchelette, 1908. *Manuel d'archéologie*, i, see p. 127 (Aurignacian fauna) and p. 134 (Solutrian fauna). Cf. p. 93 (Mousterian fauna).

[3] C. A. Weber, 1896. "Ueber die fossile Flora von Honerdingen und das nordwest-deutsche Diluvium": Abh. Naturw. Ver. Bremen, Bd. 13, pp. 413–68.

latitude farther south than Honerdingen. From the faunistic and floristic conditions, the conclusion may therefore be drawn that, during this first period of melting, the melting of the inland ice must have proceeded rapidly, and therefore cannot have occupied a long time.

None the less, the Ice Age continuously persisted right from Mousterian times, though not from their first beginning, away to the close of the Magdalenian stage. It is in connexion with that close that *the true late-glacial* stage first appears, and not till after its close does *the true post-glacial* time begin, and with it the second and final melting of the inland ice, which, like the first, was fairly rapid, as is quite clearly proved by the contemporaneous Scandinavian deposits.

It is therefore incorrect and quite misleading to use the terms 'late-glacial' and 'post-glacial' for beds deposited during the first melting stage or between the first and second cold stages of the Ice Age, between the Mousterian and the Magdalenian. Thus the deposits from these intervening stages should be called Intermediate, as they really are.

The danger of this inaccuracy cannot be better emphasized than by reference to the Magdalenian occurrences in the outposts of the Alps (Schweizersbild, Kesslerloch, Schussenried, etc.). These occur in the peripheral moraine district, and have therefore even lately been called by the archæologists 'post-glacial' (as being younger than the moraines), although in reality they are glacial, as belonging to a part of the Ice Age when the cold was as strong as ever.[1]

The same mistake has been perpetrated in the Pyrenees, where the same conditions obtained as in the Alps. There is, however, this difference, that the Pyrenean chain is comparatively small, so that the ice never had so great an extension, and may have been able to melt completely or almost completely during the first melting stage of the Ice Age. This has quite naturally given the Magdalenian occurrences in that region a still greater appearance of being 'post-glacial'.

There has already been occasion to remark (p. 421) that the first melting district of inland ice in North Germany lies between the periphery of the glaciated area and the 'circumbaltic' terminal moraine. In North Germany, then, this constitutes the Intermediate zone. The zone of oscillation here lies near the same moraine.[2]

It is north of this moraine that there first occurs the true post-glacial zone, which thus includes the whole of the Scandinavian

[1] I feel that I cannot be very hard on this mistake, since a little more than ten years ago I fell into a similar error in applying the terms 'late-glacial' and 'post-glacial' to some North German and Danish deposits, although they were so only *locally* and in reality are Intermediate. But that point of view was at that time only subsidiary to the main object, namely, to show that they could not be 'interglacial'. N. O. Holst, 1904. "Kvartärstudier i Danmark och norra Tyskland": Geol. Fören. Stockholm Förh., Bd. 26, pp. 433–52.

[2] This oscillation has long been well known from Kuhgrund, quite close to the town of Lauenburg, and is there fairly clear. It may therefore be appropriately called "the Kuhgrund oscillation".

peninsula. So far as I can see, as I have already emphasized, this is all that remains of the celebrated separate ice ages in North Germany.

The question, then, is this: Are these same three zones also found in Great Britain? I propose to show that such really is the case.

In relation to the intermediate zone of England, the Cresswell Crag caves in the north of Derbyshire are particularly illuminating, since they quite clearly show both when the inland ice came and when it went. They were excavated in 1875–6, as well as in 1878, by J. M. Mello, in part 'assisted' by Th. Heath and W. Boyd Dawkins, and were described in various memoirs,[1] among which the two from 1876 are the more important, in so far as the finds in the different layers were here kept more distinct.

That which lends to these caves their great and unusual interest is the fact that they contain well-characterized deposits of these two ages, namely, the older pre-glacial, deposited before the coming of the inland ice, and the younger intermediate, deposited after its withdrawal, both being characterized by palæolithic implements of older and younger stages and by different faunas, and still further distinguished by an erosion of the uppermost older bed. Naturally there was between the older and the younger deposits a fairly long hiatus, representing the time when the caves were blocked by the inland ice.

A section taken from Robin Hood cave by Mello in 1876 (p. 242) shows the following succession :—

Stalactite uniting breccia with roof.

(*a*) Stalagmitic breccia with bones and implements, 18 inches to 3 feet.

(*b*) Cave earth with bones and implements, of variable thickness.

(*c*) Middle red sand with laminated red clay at base containing bones, 3 feet.

(*d*) Lighter-coloured sand with limestone fragments, 2 feet (?).

Of these beds that lettered (*a*) is Intermediate, and the other layers are pre-glacial. According to Mello's figure 2 of 1876, bed (*a*) lies discordantly upon bed (*b*), and between the two is sometimes found a "bed of waterworn pebbles", which may be cemented into a conglomerate (Mello, 1877, p. 581).

[1] (*a*) J. M. Mello, 1875. "On some Bone-caves in Creswell Crags": Quart. Journ. Geol. Soc., vol. 31, pp. 679–83.

(*b*) J. M. Mello, 1876. "The Bone-caves of Creswell Crags": idem, vol. 32, pp. 240–4.

(*c*) W. Boyd Dawkins, 1876. "On the Mammalia and Traces of Man found in the Robin Hood Cave": tom. cit., pp. 245–58.

(*d*) J. M. Mello, 1877. "The Bone-caves of Creswell Crags": idem, vol. 33, pp. 579–88.

(*e*) W. Boyd Dawkins, 1877. "On the Mammal Fauna of the Caves of Creswell Crags": tom. cit., pp. 589–612.

(*f*) W. Boyd Dawkins & J. M. Mello, 1879. "Further Discoveries in the Cresswell Caves": idem, vol. 35, pp. 724–34.

(*g*) Thos. Heath, 1879. *An Abstract Description and History of the Bone-caves of Creswell Crags*; 8vo, 17 pp., Derby.

(*h*) T. Heath, 1880. *Creswell Caves v. Professor Boyd Dawkins*; 8vo, Derby.

In his "general conclusions" Boyd Dawkins (1879, p. 733) divides the mammalian fauna into three divisions: (1) the lowest, known from Mother Grundy's Parlour, with *Hippopotamus*, *Rhinoceros leptorhinus*, and *Hyæna* (abundant), therefore an older, clearly pre-glacial fauna, comparable with that from the older pre-glacial beds of Kirkdale, Victoria Cave, and Cefn Cave; (2) a later pre-glacial fauna with the forerunners of the Ice Age, mammoth and woolly rhinoceros, and in addition the reindeer, glutton, and polar-fox (the two last come from Pin Hole), which are all absent from the preceding division, but without the *Hippopotamus* and *Rhinoceros leptorhinus*; and finally (3) the Intermediate fauna, which occurs in the breccia and "differs considerably from those of the underlying strata" (Dawkins, 1876, p. 246).

The most weighty evidence, however, is furnished by the implements, and is absolutely conclusive. Boyd Dawkins and John Evans were agreed that the older implements, which as a rule are made of quartzite or ironstone, are to be referred to the older palæolithic stages; Acheulean and Mousterian were mentioned. The younger implements, on the other hand, as a rule made of flint, agree according to Evans with the Aurignacian, Solutrian, and Magdalenian, and thus belong to younger palæolithic stages. Prestwich (in the Discussion on Dawkins, 1876) remarked that the superposition of the better younger implements over the worse older ones "was better marked in this cave [Robin-Hood cave] than in any other in this country". So far as may be judged from the figures, there are found among the older implements partly Chellean (e.g. the ironstone implement, fig. 2 of 1877, p. 593), partly Acheulean (e.g. two oval implements, one of quartzite, the other of ironstone, figs. 4 and 5 of 1876, p. 251),[1] but, to whatever stage they may be assigned, all of them remain pre-glacial. Aurignacian, Solutrian, and Magdalenian, on the other hand, cannot possibly be pre-glacial. They must have come into the caves after the melting of the inland ice. From this may be drawn the important conclusion that *the inland ice melted away from the Thames Valley right up to the northern point of Derbyshire*, or perhaps still further north, *before the close of Aurignacian time.*

An equivalent of the succession in the Cresswell caves is found in North Wales in the caves near St. Asaph. In the Pont Newydd cave, together with a distinctly pre-glacial fauna (*Hippopotamus*, *Rhinoceros leptorhinus*, *Elephas antiquus*, etc.) there have been found both a human molar tooth and "quartzite implements, which may be classified with those of the lower strata in Mother Grundy's Parlour",[2] one of the previously mentioned caves at Cresswell Crags. What is still more important here, however, is the fact that in the Ffynnon

[1] Dawkins (*Early Man in Britain*, 1880, p. 180) states that the caves at Cresswell Crags yielded "implements of flint and quartzite amounting to not less than 1100". These are said to be preserved in the Manchester Museum. Of these barely a score have as yet been figured. The finds of the Cresswell caves are, however, of such great scientific importance that they deserve from archæologists a renewed and more detailed investigation than was possible in the seventies.

[2] W. Boyd Dawkins, 1880. *Early Man in Britain*, p. 192.

Beuno cave there has been found a Solutrian implement, and in Cae Gwyn cave a beautiful Aurignacian end scraper,[1] finds which clearly show that in this part of North Wales the inland ice had melted away at about the same time as in the northern district of Derbyshire.

In common with other finds, those just quoted from Derbyshire and North Wales show that it is far from correct to draw the limit for the appearance of palæolithic man "between the Wash and the Bristol Channel", as is so often done. The numerous finds of Chellean age show that during this stage man was far from rare in England. For him to have stayed to the south of such a limit would therefore have been inexplicable. It is true that the northern finds are less frequent, but this may be explained by the absence of Chalk flints from the district in question, but certainly also by the thicker moraine covering, which there conceals to a greater degree everything that is pre-glacial, to which may be added that implements of quartzite and such rocks are less easily detected than flint implements.

With regard to post-Chellean time, the possibility is not excluded that the Ice Age may have driven some part of England's palæolithic population back to the Continent, while the land bridge still existed. One is inclined to this supposition by the comparative paucity of noteworthy Mousterian localities. As such are mentioned only: Stoke Newington, Crayford, Northfleet, Dovercourt near Harwich, High Lodge near Mildenhall, and Peterborough. The more scattered Mousterian finds in the South of England, on the other hand, are less rare.

After this little archæological digression we return to one of the St. Asaph caves. H. Hicks has published a section of the Cae Gwyn cave, which shows that two inconsiderable moraine beds, separated by a layer of sand and lying on another layer of sand, overlie the intermediate cave-earth, in which has been found a flint flake and in which the previously mentioned end scraper was found.[2] He showed his section to various experienced geologists, who accepted it, and in the discussion after Hicks' paper Strahan said that he "believed that the drifts at the mouth of the cave were part of the northern drift, which he had mapped over a large part of Denbighshire, Flintshire, and Cheshire, and that the bone-earth lay beneath them". If, then, the section is quite correct, we must here at St. Asaph have a new extension of the inland ice, that is to say, we are here already within the zone of oscillation between the two melting districts of the inland ice. The correctness of such a conclusion is confirmed by the correspondence between this section with "little moraine and most sand", and sections from the North German zone of oscillation. It is also noteworthy that, while the locality Kuhgrund in the last-mentioned zone lies about on the latitude of 53° 20′–25′, St. Asaph lies in latitude about 53° 15′.

[1] H. Hicks, 1886. "Results of Recent Researches in some Bone-caves in North Wales (Ffynnon Beuno and Cae Gwyn)": Quart. Journ. Geol. Soc., vol. 42, pp. 3–17, see pp. 9, 11, figs. 5, 9.

[2] H. Hicks, 1888. "On the Cae Gwyn Cave, etc.": Quart. Journ. Geol. Soc., vol. 44, pp. 561–77, see p. 563, fig. 1.

The oscillation in question appears still more clear in the East of England at Kirmington, in the northern part of Lincolnshire, and at Flamborough in Yorkshire. Here are found beds with marine molluscs between an older and a younger moraine, affording sufficient proof of the existence of the oscillation; and it is not too bold a prophecy to assert that the future will yield many further proofs, even though they be not so clear as the sections at Kirmington and Flamborough. It is convenient to give this oscillation a special name in England also, and since it is so well known from Kirmington, the name "Kirmington oscillation" seems not inappropriate.

There now remains the question: Where does the third zone, the post-glacial zone begin? On the Continent the circumbaltic terminal moraine affords an approximately southern limit for it. This terminal moraine may be, and has been, traced from Russia, through the whole of Northern Germany and Jutland, down to the east coast of the North Sea. Can it be supposed that it is not to be found again on the west side of the North Sea? I have long had the suspicion, not to say firm belief, that the two fine terminal moraines which pass from the city of York in a north-easterly direction to the east coast of England, and are after the usual fashion of these large terminal moraines in connexion with large sandy plains, constitute this very continuation on the English side. The mapping by the Geological Survey ends, however, just by the city of York, and the westerly continuation of the terminal moraines is therefore not known, but certainly it will be possible to find it. Probably it will be traceable, not only through England, but also across the whole of Ireland. The phenomenon is far too vast a one to come to a capricious and sudden end. The task of tracing these important terminal moraines down to the Atlantic seaboard would be no unprofitable one, but I must leave it in the hands of my English and Irish colleagues.

This section on the great and geologically important distinction between the Intermediate and post-glacial zones cannot be brought to a more appropriate conclusion than by reprinting the following utterance by Boyd Dawkins:[1] "... Cumberland, Westmoreland, Lancashire, and the greater portion of Yorkshire are represented as being one of these barren areas, in which no pleistocene mammalia have been observed. It is obvious that the hyænas, bears, mammoths, and other creatures found in the pleistocene stratum could not have occupied the district when it was covered by ice; and had they lived soon after the retreat of the ice-sheet, their remains would occur in the river-gravels, from which *they are absent throughout a large area to the north of a line drawn between Chester and York*, whilst they *occur abundantly* in the glacial river deposits *south of that line*."

This was printed in 1874. It could not then be known, as we now know, that this so-called 'line' is really the great Magdalenian zone of demarcation between the Intermediate stage, with the hyæna and mammoth still existing,[2] and the post-glacial period when these creatures were extinct.

[1] W. Boyd Dawkins, 1874. *Cave Hunting*, pp. 123–4. The italics are mine.

[2] The mammoth skeleton which was found a few years ago at Borna, near Leipzig, together with Arctic plant-remains, belongs to the older part of the Intermediate zone.

Some important questions in this connexion are those relating to contemporary conditions in the North Sea. When did the Scandinavian inland ice disappear from England? Or, in other words, when did the ice cease to block the North Sea? How rapid was the elevation that began in Mousterian time, and when did there succeed the last change of level, the depression of "the submerged forests"?

During the maximum of glaciation the Scandinavian inland ice came to England in great force, and has left its traces right down the Thames Valley in the south and up to Hartlepool and Durham in the north. The inland ice, however, took a curve to the north in the neighbourhood of the North Sea, and probably also in the Sea itself. Both on the English and Dutch sides proofs of this may be seen. While in the neighbourhood of London the ice comes quite close to the Thames Valley; on the coast of the North Sea it does not come further than to the district between Suffolk and Essex; and while in Holland it comes near the Rhine, where this river runs into the Dutch district, on the coast it reaches only down to the southern end of the Zuyder Zee. The same conditions obtained at the beginning of the post-glacial time, when the southern limit of the inland ice is precisely indicated by the large terminal moraine. From York, in latitude 52° 52′–53′, the terminal moraine passes to the north-east, and on the continental side the greater melting in the neighbourhood of the North Sea is still more clearly accentuated. The circum-baltic terminal moraine, coming from the east, has a direction east and west, but takes a sharp turn northward as it passes from Mecklenburg into Holstein, and here, as well as in Schleswig, comes much closer to the east than to the west coast, after which, in Jutland, it takes a new western curve down to the coast of the North Sea, which it first meets in latitude 56° 30′.

Here the important fact must be recalled that on the continental side within the Intermediate zone there have been found marine deposits, "Arctic clay covered by boreal sand," along the east coast of the North Sea, from Lamstedt and Basbeck south of the Elbe in the south up to the Jutland locality, Hostrup, in the north. Intermediate localities are Burg and Esbjerg. The most southerly occurrences lie at a height of 5 to 7 metres above sea-level, the most northerly at a height of 27 metres,[1] from which follows the conclusion that at the time of their deposition the land was more depressed in the north than in the south. Further, since these beds, deposited in an open North Sea, show by their Arctic character and in other ways that they belong to the earliest portion of the Intermediate stage, the conclusion follows that the blocking of the North Sea by the Scandinavian inland ice ceased quite early, probably shortly after the disappearance of the Hesbayan lake, or, in other words, just at the beginning of the Intermediate time.

The elevation of the land at that time is, naturally, not easy to prove, since that part of the sea-floor which then lay above the surface of the water now lies sunk beneath it. The post-glacial changes of level on the other hand appear simpler, and if, as is

[1] Holst, 1904. *Kvartärstudier*, etc., pp. 433–9.

probable, they proceeded in analogous fashion to the last Scandinavian movements, they may be supposed to have taken place somewhat in the following way.

After the inland ice during post-glacial times had melted so much that its pressure was notably diminished, the whole of Scotland, and perhaps also the most northern part of England, began to rise, but at the same time the remaining part of England sank. In a word the land behaved something like a see-saw; when the one (northern) end went up, the other (southern) end went down. Probably both the up and the down movement increased with distance from the fulcrum of the see-saw, that is, from the line of equilibrium, which in this particular case seems to have been the border between England and Scotland. At any rate, something similar was the case in Scandinavia, where the line of equilibrium is held to proceed in Denmark from Nissum Fiord west of Holstebro, lat. 56° 20′ N., on the west coast of Jutland in the north, down to the northern part of Falster in the south.[1]

In Southern Scandinavia this change of level carried with it the evident and very interesting result that the well-known kitchen-middens, which originally lay on the shore very little above sea-level, have come to lie higher and higher *above* sea-level the further they are north of the Nissum–Falster line, but lower and lower *under* sea-level the further they are south of that line. Thus the kitchen-middens at Kolding now lie 3 to 4 metres below sea-level, but the kitchen-middens in Kiel Harbour, 140 kilometres further south, are not less than 9 metres below sea-level.

If this result is applicable to England, it is clear that the English kitchen-middens, as well as all coast deposits approximately contemporaneous with the Danish ones, must now lie below sea-level, and be therefore inaccessible. The so-called Hastings kitchen-midden is merely a fisherman's dwelling-place of far later neolithic date.

The circumstances just mentioned can therefore in no way be adduced as evidence against the idea that the kitchen-midden civilization and its bearers came to the north by the so-called 'western way' or the Atlantic coast road. I am the more convinced of this since I consider that it can be shown, and in part indeed already has been shown, that Egypt, which, during the pluvial epoch was a 'promised land', was also a centre of civilization for the whole of Europe right from the earliest palæolithic time down almost to the close of the Stone Age, and in general sent its civilization into Europe by the roads along the south and west of the Mediterranean. Clearly this was still so after the kitchen-midden time, as shown by the distribution of the megalithic monuments — the dolmens and the long barrows or chambered barrows (in Swedish: *gång-grifter*). For these monuments follow without exception the Atlantic coast lands—France, England, and Holland, to continue subsequently over North Germany to Scandinavia, but are not found in the interior of Europe. Therefore it cannot be correct to consider the main neolithic immigration to Scandinavia

[1] N. V. Ussing, 1913. *Danmarks Geologi*, København, see pp. 327–8.

as having been Indo-European and coming by the 'eastern way', a view which none the less is still generally held in Scandinavia. But it is plain that, if the western way of migration to the north was still used as late as the time of the long barrows, so much the more probably was it that road which was used during the preceding stage of the kitchen-middens.

The end of my task is now reached. Within the limits of Great Britain the Ice Age can be followed from its beginning to its end. England has the further advantage of having already possessed quite a numerous population before the Ice Age, and has been inhabited ever since. Archæology can therefore lend a strong support to glacial geology. It was these fortunate English conditions which originally gave me the idea of attempting this brief general synopsis of the course of the Ice Age in this country. I cannot, however, lay down my pen without expressing my hearty thanks, in the first place to England, which, in the midst of this world-war and general disturbance, has given me a calm and peaceful lodging from the very beginning of the war, when I came here headlong, down to the present when I return to my Fatherland; and also to my English friends, new and old, unnamed but unforgotten, who have lent me a hand and facilitated my geological studies in England.

V.—The Crawfordjohn Essexite and Associated Rocks.

By Alexander Scott, M.A., B.Sc.

(*Concluded from the October Number, p. 461.*)

ANOTHER type, which is found in both quarries and which under the microscope has the aspect of a monchiquite or limburgite, probably represents the actual marginal rock of the intrusion.[1] It consists of small microphenocrysts of augite and olivine in a dark matrix, which can be resolved into granular augite and magnetite in a nearly isotropic base. The latter, which sometimes contains felspar microlites, seems to be mainly analcite with some nephelite, as it can be readily gelatinized and stained, while the refractive index is very low. The felspar microlites are small and sometimes have a rough trachytic structure resembling that of the mugearites. Following Harker's suggestion that augite-olivine rocks with an isotropic base should be classed as limburgites when the base is glass and as monchiquites when it is analcite,[2] this rock can be included in the latter group. The parts which are richer in felspar may be termed analcite-basalts.

A sample of monchiquite from the large quarry has been analysed, and the results are given in column 1, table iii. The rock does not differ much in chemical composition from the essexite. The silica content, however, is noticeably lower, while the amounts of iron oxides and alumina are slightly higher. While the amounts of augite in the two rocks are probably very similar, the increase in magnesia and ferrous oxide in the monchiquite, coupled with the lower silica-content, indicates a greater proportion of olivine.

[1] This rock was first brought to my notice by Mr. W. R. Smellie.

[2] *Petrology for Students*, 4th ed., 1908, p. 158.

Analyses 2 and 3 represent two basic monchiquites, and the fact that the Craighead rock is intermediate in composition between these two, shows a close relationship to this group. A recalculation of analysis 2, after deduction of the amount of CO_2, would bring it fairly close to analysis 1. A comparison of columns 1 and 4 indicates a high degree of affinity with the nephelite basalts. Several occurrences of the latter have been noted among the Carboniferous lavas and intrusives of the Midland Valley,[1] where they exhibit some

TABLE III.

	1.	2.	3.	4.	5.	6.
SiO_2	40·79	37·34	42·03	40·01	40·60	40·10
TiO_2	1·79	3·93	3·70	1·45	4·20	2·98
Al_2O_3	15·54	11·84	13·60	13·44	12·55	15·50
Fe_2O_3	3·90	5·37	7·55	5·32	5·47	6·35
FeO	9·48	6·40	6·65	7·22	9·52	7·29
MnO	·20	·18	tr.	·30	—	—
MgO	8·61	9·66	6·41	9·46	8·96	8·41
CaO	12·71	11·92	14·15	14·06	10·80	12·40
Na_2O	3·44	2·91	1·83	3·38	2·54	3·37
K_2O	2·05	2·05	·97	1·90	1·19	1·67
H_2O +	·60	2·56	1·08	1·94	2·28	·87
H_2O −	·58	·24				
P_2O_5	·47	·04	·57	1·36	2·68	1·28
CO_2	not found	5·08	—	—	—	—
(Ba . Sr.) O	tr.	·04	—	—	—	—
	100·16	100·09	99·23	99·84	100·79	100·22

1. Monchiquite, Craighead, analyst A. Scott.
2. Monchiquite, Mile End, Montreal (includes ·47 $Fe S_2$), analyst M. F. Connor.[2]
3. Monchiquite, Pulaski Co., Arkansas, analysts Noyes & Bracket.[3]
4. Average of ten analyses of nephelite-basalt.[4]
5. Camptonite, Maena, Norway, analyst L. Schmelk.[5]
6. Ijolite, Ambaliha, Madagascar, analyst Pisani.[6]

similarity with the Hillhouse type,[7] merely differing from it in the presence of nephelite and the smaller amount of olivine. Since the Hillhouse basalts may be regarded as the microporphyritic equivalents of the Craiglockhart type, it is significant that, while the Craighead aphanites are related to the former, the essexites are not far removed from the latter.[8] Analyses 1 and 6 resemble each other so closely that the Madagascar ijolite may be regarded as a plutonic equivalent of the rock under consideration.

The microscopical and chemical examinations of the Craighead rocks give some clue as to the nature of the differentiation. The augite of the marginal rocks is zoned to a much greater extent than

[1] E. B. Bailey in *Geology of East Lothian* (Mem. Geol. Surv.), 1910, p. 99, pp. 105–13.

[2] Geological Congress, Canada, 1913, Guide-book No. 3, p. 46.

[3] Quoted in Iddings, *Igneous Rocks*, vol. ii, p. 413, 1913.

[4] Compiled from H. Rosenbusch, *Elemente der Gesteinslehre*, 3rd ed., 1908, and J. P. Iddings, *Igneous Rocks*, vol. ii, 1913.

[5] W. C. Brögger, loc. cit., p. 26.

[6] A. Lacroix, loc. cit., p. 138.

[7] Cf. J. S. Flett, loc. cit., p. 316; E. B. Bailey in *Geology of Glasgow District* (Mem. Geol. Surv.), 1911, p. 138.

[8] Cf. E. B. Bailey, loc. cit.

the mineral of the essexites, and shows a greater difference between the extinction angles of the inner and outer zones. This points to the former mineral crystallizing during a rapid fall of temperature, since the tendency of mix-crystals to show zonal structure increases with the rate of cooling during crystallization, owing to the shorter time available for readjustment of equilibrium. Hence it is feasible to assume that the 'chilling' set in before the pyroxene began to crystallize. There is, however, very little difference between the olivine of the two rocks, which suggests that this mineral commenced to crystallize before the inception of rapid cooling. While the relatively greater amount of olivine in the chilled rock is doubtless partly due to the rapid cooling ensuing before the olivine had finished crystallizing, and hence preventing, to some extent, resorption and subsequent reprecipitation as pyroxene,[1] the main factor seems to be the difference in chemical composition, i.e. the greater amounts of magnesia and ferrous oxide and the smaller silica content.

This difference in composition may be explained in two ways. Firstly, it may be due to the migration of orthosilicate molecules to the cooling margin during the crystallization of the olivine. This migration may have taken place by diffusion, as suggested by Harker,[2] or by means of convection-currents, as advocated by Becker[3] and Pirsson.[4] Washington's view[5] that it is to be attributed to "the force of crystallization", which is supposed to be capable of acting at an appreciable distance, can be explained in terms of the diffusion hypothesis in the following way. The concentration of a solution in the immediate neighbourhood of a growing crystal will be lowered by the tendency of the molecules of the solute to attach themselves to the crystal. Hence an osmotic-pressure gradient will be set up, and in order to restore equilibrium there will be a transference of molecules by diffusion from the remainder of the solvent. The second explanation of differentiation of this type is due to Bowen,[6] and is based on the gravity-separation of the crystals. While the minerals of early formation (in this case olivine) are crystallizing, the action of gravity tends to make them sink. In the chilled margin, however, the rate of cooling is sufficiently rapid to prevent this sinking taking place to the same extent, as it is hindered not only by increasing viscosity but also by the crystallization of the remaining minerals. The second explanation has the advantage over the first in being based on experimental work and being less dependent on hypothesis. In the present case, however, the depth of exposure is too small for the detection of any gravity sinking in the essexite, though it is possible that a more basic layer may exist at a greater depth. It is noteworthy that while the essexite has nearly the same chemical composition as the Brandberget rock, the monchiquite

[1] N. L. Bowen, Amer. Journ. Sci. [4], xxxviii, pp. 256–8, 1914.
[2] A. Harker, *Natural History of Igneous Rocks*, 1908, pp. 317–20.
[3] G. F. Becker, Amer. Journ. Sci. [4], iii, pp. 21–8, 1897.
[4] L. V. Pirsson, Bull. U.S. Geol. Surv., No. 237, pp. 187–90, 1905.
[5] H. S. Washington, Bull. Geol. Soc. Amer., xi, pp. 409–10, 1900.
[6] N. L. Bowen, Amer. Journ. Sci. [4], xxxix, pp. 175–90, 1915.

closely resembles the camptonite (column 5, table iii), which Brögger regards as a complementary differentiate of the essexitic magma of the Gran district.[1]

The Contact Metamorphosed Rocks.—In both quarries an interesting set of altered rocks is found in contact with the margin of the intrusion. The sediments range from greywackes and grits, of varying degree of coarseness, to fine-grained mudstones and shales. The grits and greywackes, which consist of rounded grains of quartz and felspar, together with rock-fragments, are not much altered, the alteration being more or less confined to the matrix, and being therefore more noticeable in those rocks with a comparatively small proportion of granular material. In the more altered rocks the grains seem to have undergone some corrosion, while the matrix has been completely recrystallized. The chief 'new-formed' minerals comprise ilmenite, in small eumorphic crystals, which are often brown in colour and translucent, and small greenish prisms with a good cleavage, which seem to be muscovite altering to chlorite. The remainder of the matrix, which is stained by iron oxide, is felsitic in structure and appears to be an aggregate of felspar. Some of the rocks contain microlites of felspar, while others have bunches of hair-like crystals, which are probably rutile, and sporadic flakes of strongly pleochroic biotite.

The shales, however, have undergone a much greater amount of metamorphism. In one rock which occurs in the large quarry numerous lath-shaped crystals can be seen in the hand-specimen, while within the space of 3 inches there is a passage to a thoroughly aphanitic, compact rock with no recognizable minerals. Under the microscope the former rock shows rather a remarkable structure, as it consists entirely of interlocking, irregularly shaped crystals of colourless cordierite, which enclose all the other constituents. The outlines of the cordierite grains are not usually visible in ordinary light, but between crossed nicols the crystals appear as irregular prisms. Simple twinning is very common, but multiple and complex twins are rare. Of the enclosed minerals, muscovite, often altered to chlorite, is the most abundant. Biotite and ilmenite are also present and occasionally predominate in certain bands, the determining factor being the composition of the particular band. This cordierite-hornfels has a close resemblance to the cordierite schist described by Harker from the Skiddaw district.[2] Not only is the cordierite quite fresh and unaltered in both instances, but it also constitutes a coarse-grained groundmass in which the remaining, much smaller, crystals are set. As the compact rock is approached the grain-size of the cordierite diminishes and the crystal boundaries become indistinct, so that finally the rock consists of small crystals of muscovite with subordinate biotite and rutile in a fine-grained matrix of cordierite.

Another type of altered argillaceous rock occurs in the small quarry and also further up on the hillside. Under the microscope, the rock is seen to consist of a great abundance of minute crystals of muscovite with subsidiary ilmenite in a groundmass, which is partly composed

[1] W. C. Brögger, loc. cit.
[2] A. Harker, *The Naturalist*, pp. 121–3, 1906.

of dusty cryptocrystalline material and partly of clear grains of felspar. Under a low-power objective the latter appear as small rhomb-shaped crystals, but a high power shows that they are irregular in shape and have no definite crystal boundaries, merging gradually into the dusty material. The felspar seems to be an acid oligoclase as the refractive index is sometimes below that of Canada balsam and sometimes above. This rock has some resemblance to a fine-grained adinole, and only differs from the latter in the presence of some anorthite in the felspar.[1] A portion of the soda in the mineral has probably been introduced from the intrusive rocks and the fact that oligoclase is present, instead of albite as in the typical adinoles, may possibly be ascribed to the presence of calcium oxide in the original sediments. One fact in favour of the idea that the intrusive rock is the origin of the soda is the existence of numerous veins of adinole much coarser in grain than the rest of the rock. These veins consist of a core of muscovite, sometimes replaced by decomposition products and flanked by bands of clear felspar. In other cases, the relative disposition of the mica and felspar is quite irregular. The veins often cut across the bedding planes in an irregular fashion, but occasionally they lie along the latter. This is particularly the case along the junction of two different types of sediment, which are usually found separated by a band of fairly coarse adinole.

In the disused quarry, several types of rock, whose original nature is doubtful, are found. One type, which in the hand-specimen shows faint spherulites, is seen under the microscope to consist of numerous microcrystalline patches set in a cryptocrystalline matrix. The former consist of groups of clear felspar, permeated with dark material, which under a high-power objective can be resolved into aggregates of greenish microlites apparently of a pyroxenic nature. Dark elongated masses of similar material are scattered throughout the groundmass and appear to represent former crystals of mica or hornblende. Occasionally new-formed ilmenite is found. Sometimes clots and bands of a rather different nature are found enclosed in this rock. The ferromagnesian areas are more rounded, while the felspar, which occurs as small laths, is uniformly distributed throughout a cryptocrystalline groundmass. The felspars appear to be oligoclase, as they have a low extinction angle and a refractive index above that of Canada balsam. Parts of the groundmass have a lower refractive index, and may be orthoclase.

As the intrusion is approached the felspathic rock assumes a more decidedly porphyritic aspect. The felspars, which show broad rectangular sections, are sometimes arranged in groups and sometimes found as single crystals. The mineral is perfectly colourless and fresh and sharply delineated from the groundmass. Carlsbad twinning is universal and albite twinning fairly common, while occasional striations following the pericline law can be observed. The refractive index and extinction angles indicate a composition approaching andesine. Occasionally phenocrysts of orthoclase are also found.

[1] Cf. J. Roth, *Chemische Geologie*, vol. iii, 1893, pp. 141–4; H. Dewey & J. S. Flett, GEOL. MAG. [5], vol. viii, pp. 243–4, 1911.

Dark aggregates of ferromagnesian microlites suggest the original presence of porphyritic mica or hornblende. The groundmass is generally felsitic and, from the refractive index, seems to contain a fair amount of orthoclase, a fact borne out by the quantity of potash in the analysis. This rock has been analysed, the results being given in column 1, table iv. In chemical composition it closely resembles the albite-diabase of Trusham, Devon (column 2), while it also shows some similarity with the keratophyres. The former rock consists mainly of broad rectangular crystals of alkali-felspar with interstitial chloritic material, and is therefore very like the crystalline aggregates in the Craighead rock. In the neighbourhood of Abington there are several outcrops of lavas and intrusive rocks of Ordovician age, and it seems probable that the rock in question is related to these. The felspars are so fresh that they must

TABLE IV.

	1.	2.	3.	4.
SiO_2 . .	58·25	58·47	64·38	58·80
TiO_2 . .	1·08	1·18	—	·40
Al_2O_3 . .	15·52	16·11	16·98	17·03
Fe_2O_3 . .	2·26	·85	4·04	2·44
FeO . .	6·00	6·90	—	5·81
MnO . .	·12	·46	—	—
MgO . .	2·20	1·58	·28	1·83
CaO . .	2·14	·94	1·08	1·16
Na_2O . .	4·81	4·34	7·57	5·22
K_2O . .	4·26	5·18	4·30	4·27
H_2O+ . .	3·03	2·08	1·64	2·68
H_2O- . .	·67	·48		
P_2O_5 . .	·08	·27	—	·11
CO_2 . .	not found	1·34	—	·75
	100·42	100·31	100·27	100·61

1. Altered lava (?), Craighead, analyst A. Scott.
2. Albite-diabase (felspathic type), Trusham, Devon, analyst E. G. Radley (includes ·07 Cl., ·08 BaO, ·03 FeS_2).[1]
3. Keratophyre, Hamilton Hill, Peebles, analyst J. J. H. Teall.[2]
4. Keratophyre, Blankenburg, Harz (includes ·11 SO_3).[3]

have been completely recrystallized and their composition and form suggest some infiltration of material from the essexites. The felspars of the diabases of Devon and Cornwall are usually albitized, a phenomenon which also occurs in the Southern Uplands. The relatively basic nature of this mineral in the Craighead rock may be due, as suggested above, to the introduction of material during the metamorphism. This renders the determination of the original nature of the rock difficult, but it seems probable, from a consideration of the chemical analyses, that it was originally a felspathic diabase or proterabase, resembling a trachyte in composition and having porphyritic crystals of felspar and either mica or hornblende in a fine-grained or glassy matrix.

A thin band in the greywacke above the quarry appears to have

[1] J. S. Flett in *Geology of Newton Abbot* (Mem. Geol. Surv.), 1913, p. 62.
[2] J. J. H. Teall in *The Silurian Rocks of Scotland* (Mem. Geol. Surv.), 1899, pp. 88–9.
[3] Quoted in Rosenbusch, *Elemente der Gesteinslehre*, 3rd ed., 1910, p. 343.

been a tuff, as it contains rounded but clear crystals of felspar, abundant dark aggregates of ferromagnesian crystallites and fragments of a rock which was probably an andesite. The felspar has again been recrystallized, and the shape of the microlitic patches indicates former phenocrysts of hornblende. In the andesite fragments small clear felspar laths are found, as well as an altered bisilicate mineral in which occasionally unaltered traces of augite appear.

As a whole, the metamorphism differs from that developed round the granites of the Southern Uplands, in the absence of such characteristic minerals as andalusite and garnet.[1] Although the sediments are so much obscured as to preclude any possibility of examining their progressive metamorphism, it is very probable that the altered aureole is narrow, extending to not more than a few feet.

Nature and Age of the Intrusion.—Judging from the extent of the exposures, the intrusion is not less than 250 yards long and 25 yards broad. Indeed, the breadth is probably much greater as the most southerly exposure is a very coarse-grained rock. If it were a dyke, it might be expected that it would be seen in the Duneaton water, 400 yards to the north-west and 200 feet lower than the large quarry. Although the grits and greywackes are exposed along the bed of the stream, no trace of igneous rock could be found, either in the stream or on the opposite hillside. Further, there is no evidence of any continuation to the south-west, on Craighead hill or in the Clyde Valley. The nature of the igneous rocks, as well as the field relations, indicates that the intrusion is probably a small elongated boss. Its form is rather like that of the Lennoxtown essexite which, although originally described by the Geological Survey as "an irregular dyke of great thickness",[2] is classed in the Glasgow memoir as "an elongated plug or small boss".[3] The Craighead intrusion may be regarded as very similar, not only morphologically but also lithologically, the only difference being the absence, so far as is known, of any chilled margin in the Lennoxtown occurrence. Although the Geological Survey express no definite opinion regarding the age of the latter, they indicate that it is probably Carboniferous or Permo-Carboniferous. There does not seem to be any doubt that the Craighead intrusion has no connexion with the Kainozoic dykes, and that it must be referred to the late Palæozoic alkalic suite. Its great petrographical resemblance to the Ayrshire representatives of the latter group is strongly in favour of this, and, although the field evidence only indicates a post-Llandeilo age, the lithological evidence seems to preclude any connexion with either the Old Red Sandstone or Kainozoic rocks. Adopting Tyrrell's suggestion that the dominantly alkali rocks of late Palæozoic age are Permo-Carboniferous,[4] the Craighead intrusion may be referred to this epoch.

[1] Cf. M. I. Gardiner, Quart. Journ. Geol. Soc., xlvi, pp. 569–81, 1890; J. J. H. Teall, loc. cit., pp. 632–49.

[2] Summary of Progress of Geological Survey for 1907–8, p. 55; ibid. for 1908–9, p. 45.

[3] E. B. Bailey, *Geology of Glasgow District* (Mem. Geol. Surv.), 1911, p. 113.

[4] G. W. Tyrrell, Trans. Glasgow Geol. Soc., xiii, p. 311, 1909; GEOL. MAG. [5], ix, pp. 129–31.

NOTICES OF MEMOIRS.

Papers read before Section C (Geology), British Association, Manchester, September, 1915.

I. The Classification of the Tertiary Strata by means of the Eutherian Mammals. By Hon. Professor W. Boyd Dawkins, M.A., D.Sc., F.R.S.

THE classification of the Tertiary strata by means of the higher mammalia outlined in my paper before the Geological Society in 1880[1] has been tested by the many discoveries all over the world since that time, and not found wanting. The details have been filled in, and the principle adopted has been proved to be of worldwide application to North and South America and to Southern Asia and Africa as well as Europe, the living mammalian species in each geographical province being taken as the standard. It has been accepted by Osborne and others, and is now being used for the grouping of the Tertiary strata of America. It has been used in the organization of the Manchester Museum. It is therefore fitting that it should be brought up to the knowledge of to-day.

The classification is based on the evolution of the mammalia, the only group in the animal kingdom that was, as Gaudry writes, "en pleine évolution" in the Tertiary Period, all the lower forms having already undergone their principal changes and none changing fast enough to be of service in defining the stages. The scheme is as follows:—

Table of the Divisions of the Tertiary Period.

Descriptions.	*Characteristics.*
Historic, in which the events are recorded in history.	Modern types of man. Man the master of nature.
Prehistoric, in which man has multiplied exceedingly and domesticated both animals and plants. Wild Eutheria on the land of existing species, with the exception of the Irish elk.	Modern types of man. Cultivated plants. Domestic animals—dog, sheep, goat, ox, horse, pig, etc. Wild Eutheria of living species.
Pleistocene, in which living species of Eutheria are more abundant than the extinct species. Man appears.	Extinct types of mankind. (Modern types?) Living Eutherian species dominant. Man.
Pliocene, in which living Eutherian species occur in a fauna mainly of extinct species.	Living Eutherian species present. Extinct species dominant.
Miocene, in which the alliance between living and extinct Eutheria is more close than in the preceding stage.	No living Eutherian species. Living Eutherian genera appear. Anthropoid apes. Extinct genera dominant.
Oligocene, in which the alliance between extinct and living Eutheria is more close than in the Eocene.	No living Eutherian genera. Living families and orders. Extinct families and orders numerous.
Eocene, in which the Eutheria are represented by living, as well as by extinct, families and orders.	No living Eutherian genera. Living families and orders. Lemuroids. Extinct families and orders dominant.

The most important break in the succession of life-forms occurs at the close of the Oligocene age in Europe and America. From this

[1] Q.J.G.S., pp. 379–404.

break down to the present day the continuity is so marked that we may conclude that the present face of the earth is merely the last in a long succession in the Tertiary Period.

II. The Carboniferous Limestone Zones of N.E. Lancashire. By Albert Wilmore, D.Sc.

THE sequence is well seen in the neighbourhood of Clitheroe, where numerous quarries have been opened up. The lowest beds exposed are near Chatburn Mill, and are dark, thinly-bedded limestones with calcareous shale partings. Fossils are very scarce. There is a great thickness of these almost unfossiliferous beds, the top parts of which are dolomitic.

Bold Venture Quarry, Horrocksford Quarry, and several other exposures show beds in probably lower zone C, with numerous small Zaphrentids (chiefly *Zaphrentis omaliusi*, with the variety *ambigua* of Mr. R. G. Carruthers very common). Higher parts of these beds contain *Caninia cylindrica*, which has been found at Brungerley Bridge, in Bold Venture Quarry, at Pimlico, and at Downham. This species is not so common or well developed as in beds farther east, towards Hellifield and district. Among the Brachiopods are *Chonetes comoides*, *Orthotetes crenistria*, etc. Large Gasteropods such as *Euomphalus pentangulatus* and *Bellerophon cornuarietis* are common. *Conocardium hibernicum* is a characteristic Lamellibranch.

Above these beds come the lowest beds with *Productus sub-lævis*, and the Knoll beds of Coplaw, lower part of Worsaw, etc. Here are the typical zone C, knolls with numerous Brachiopods, the Gasteropods mentioned above, but few Corals. *Amplexus coralloides* is, however, common and *Michelinia* sp.

Above these are well-bedded crinoidal limestones leading up to the knolls of Salt Hill, Bellman Park, Worsaw, etc., which are probably in the upper C or lower S of Dr. Vaughan's zonal scheme. These beds contain a rich Brachiopod fauna, quite distinct, however, from that of Elbolton. Whilst *Productus pustulosus*, *Pr. semireticularis*, *Spirifer striatus*, etc., are quite common, one never finds *Pr. striatus*, *Pr. martini*, and other *D.* forms so common in those eastern knolls.

A fairly rich coral fauna has lately been discovered in these higher Clitheroe knolls; it has not yet been worked out, however. There is probably an unconformity at this level, and then there succeeds a great thickness of shales with limestones, with few fossils. These would appear to be on the same horizon as the richly fossiliferous beds of Elbolton. Above these shales with limestones come the Pendleside limestones, black limestones with cherts, and with irregular bands of more fossiliferous limestone. The Ravensholme limestone appears to be similar and to contain some of the same fauna as the highest limestone at Cracoe and the limestone of the railway quarry at Rylstone described by the writer.

The Bowland shales succeed these beds, and lead up to the Millstone Grit series. A map was exhibited on which some of these generalizations were shown.

REVIEWS.

I.—A Review of Report of the Excavations at Grimes Graves, Weeting, Norfolk. 8vo; pp. 254. Prehistoric Society of East Anglia. London: H. K. Lewis, 1915. Price 5*s*.

THE prehistoric flint mines known as Grimes Graves recently acquired new interest from the suggestion that they might be of Palæolithic age, contemporary with the Cave deposits of England. The fact that this conclusion, if justified, would completely upset all our ideas as to the history of Britain in late Pleistocene time makes it necessary for geologists to take notice of the important work of which this is a review.

Two pits and their associated galleries were almost completely cleared by a committee financially assisted by many institutions and individuals.

The excavations were supervised by Mr. A. E. Peake, who gives an admirably clear account of them, followed by an equally excellent description of the cleared pits and a discussion of the mode of infilling. These diggings, obviously carried out with great skill and care, reveal the following facts, which in the main merely confirm Canon Greenwell's results of forty years ago. The mines consist of shafts, about 30 feet deep, widely funnel-shaped above but with more vertical sides below, of rather accurately circular form, and with a minimum diameter of about 12 and a maximum of about 30 feet. The bottom of the pit is supported by a 'shaft pillar' pierced by about half a dozen galleries which lead into an irregular series of chambers, or perhaps more accurately a general excavation, in which the working faces are so arranged as to leave pillars, as in the pillar and stall method of coal-mining.

The flint worked occurs as a layer of nodules lying on the bed which forms the floor of the galleries. The immense amount of debris from the shaft and galleries was disposed of either by dumping into a neighbouring disused pit, having been hoisted out of the hole by a rope which cut grooves in the side walls at various places, or in later stages by packing it away in disused galleries. The work of excavation was almost entirely performed with picks of red deer antler, whose marks are shown in the chalk, and of which a very large number of broken and worn-out specimens were found in the galleries and fillings.

Some of the cuts in the walls of the galleries were not made by bone picks but by both chipped and ground axes, an observation which confirms Canon Greenwell's discovery of a ground basalt axe in his pit, which has been quite gratuitously questioned. These axes, however, were only used to a slight extent. The flints when extracted were broken up by blows from the back of the picks or from an isolated flint hammer.

Between and round the pits are floors where the blocks of flint were worked up; these are marked by the great mass of scraps and roughly chipped blocks. The animal remains, both mammals and molluscs, belong entirely to living species, and include sheep and oxen,

both in all probability domesticated. The articles of human workmanship, except for the red deer antler picks, are described, with a fine series of "minimum shading" line drawings, by Mr. R. A. Smith.

It is an astonishing feature of this lengthy discussion that nowhere is there any indication of the most abundant type of implement found, and that it is largely concerned with rare or unique forms. Working, as this author was, with an enormous mass of refuse from a factory, it is curious that he makes no attempt to discuss the method of manufacture of any type, and that he remarks that "it is to be hoped that 'prehistorians' will no longer countenance the ridiculous notion that the majority of the Grimes Graves flints are nothing but celts in various stages of manufacture". Why such a notion should be ridiculous he does not explain; any personal experience of workshops in countries till recently inhabited by stone-using savages, be it in North America, South Africa, or Australia, will show that an extraordinary lack of finished tools and an enormous abundance of incompletely finished ones, is eminently characteristic of such sites.

Judging solely from the figures and description in this work under review, the commonest type is that which under slightly different forms is represented in figs. 24, 25, 26, 29, 36, 55, 57, 61, 66, 75; this type is also the commonest at Cissbury, judging from specimens in collections. Two other types described by Mr. Smith, represented by figs. 54 (70?) and 74, which are said to be common, must be discussed in connexion with them. No. 54 is a thin, well-chipped blade exactly like the butt of the celt-like form in 24. No. 74 is a thin well-chipped flint with a broad cutting-edge. Both these 'implements' terminate in a slightly oblique fracture. Both are well represented in the Cissbury series at the Manchester Museum, which indeed contains one of each, which fit together and form a single complete celt-like form! That the break in this is an ancient one is shown by the fact that the implement so completed is particoloured, one face of the butt and the other face of the edge being white patinated.

That this implement is not only celt-like, but really is a celt, is certain. Unaltered examples do occur as surface finds in South-Eastern England, and specimens with a variable amount of grinding are not at all uncommon, that vary from axes in which the whole plan of the flaking is quite visible, little but the actual edge being ground, to nearly smooth examples which retain the unsymmetrical section common with rough blanks. Some of the other forms figured by Mr. Smith are of course not celts nor even blanks for their manufacture.

The remarkable specimen, fig. 23, which resembles the tapering portion of a Chelles ficron, is exactly paralleled by a much more remarkable specimen in Manchester, in which the tool is completed beyond the abrupt end of Mr. Smith's example, which is of course nothing but a break, by a thick portion which is ground and polished to the typical segmental edge of a neolithic axe; chipped and polished portions alike are covered by the same white patina.

There seems to be absolutely no escape from the conclusion that

these celt-like forms are actually neolithic celts, made as blanks for trade, exported as they stood, and used either rough or after more or less grinding by their 'purchaser'. That such a type of trade is not only possible but probable will be obvious to anyone who will examine in the American Museum of Natural History in New York, or in the Field Museum at Chicago, the immense series of Indian implements which show all stages, from the rough blanks sometimes found in Illinois and Wisconsin in enormous caches of several thousand, to well-finished knives or spear-heads.

Yet in the face of this evidence (which has been available for years) and of the fact that this celt-like form with more or less parallel sides and a segmental edge cannot be matched in cave series, although they are the dominant type at Cissbury and Grimes Graves, Mr. Smith obviously inclines to the idea that the whole series are of an age intermediate between Le Moustiers and Aurignac. This remarkable view is really founded on the occurrence at the Graves (and also at Cissbury) of disc-like flints, very like late Acheulian types and of others resembling 'hand-axes'. The extraordinary implement mentioned above with a neolithic ground axe-head at one end and the point of a Chelles ficron at the other, both obviously of the same age, show that supposititious river-drift type did continue into the age of polished stone. The idea that the industry (for it is obviously only one industry) is of Mousterian age is founded largely on the occurrence of a tortoise core and a couple of flakes of 'Levallois type', a type by the way which was probably not used in later Mousterian time, but surely the great cores of Pressigny are nothing but tortoise cores, rather better made and of post-Palæolithic date? Apart from these the whole argument rests on a series of often unique pieces which may be paralleled in various cave cultures. Argument of this type, the comparison of exceptional tools of one site with exceptional tools of others (of various ages) when the general series are totally different, is surely reducing the study of the cultural stages of stone-using man to an absurdity. Messrs. Mahoney & Kenyon have exhibited in the Melbourne Museum a series of stone tools from modern Australian camps which exactly match the European implement of all the Palæolithic stages placed alongside them; sporadic resemblances of occasional implements to earlier and far removed types are very common; only a few months ago the present writer picked up a typical though small Mousterian point, associated with Indian arrow-heads in Texas.

Mr. Smith asks if the Graves are neolithic, why do we not find polished axes and arrow-heads? Why should we do so? Does the modern flint knapper go to his work accompanied by an axe and a shot-gun? Why should the prehistoric artisan take with him an expensive polished stone axe when a crude unpolished one or a deer horn pick will do his work equally well, and why should he leave arrow-heads, also comparatively expensive, amongst the waste material of his workshop? As these very excavations have shown, polished axes were in existence whilst this industry was flourishing, and until Mr. Smith can produce a polished axe found by a reliable

Dr. CHARLES CALLAWAY.
Died 29th September, 1915.

investigator in an undisturbed cave in a Mousterian layer it is no good adducing stray parallels or evidence of a Palæolithic age for Grimes Graves, and by analogy for Cissbury and Spiennes and other sites. The complete absence of any extinct mammalia or mollusca and the presence of sheep and domesticated oxen are, of course, very strong evidence against a Palæolithic age for this remarkable locality of mining industry.

II.—C. W. Gilmore. A New Restoration of *Stegosaurus*. Proc. U.S. Nat. Museum, vol. xlix, 1915.

In a recent publication (Bull. 89, U.S. Nat. Museum) Mr. Gilmore has given an exhaustive account of the osteology of *Stegosaurus*, and has discussed the various restorations of that curious reptile hitherto published by different authors. In the present paper he gives a new restoration embodying the results of his own researches, and probably representing the nearest approach to accuracy that is likely to be attained. He comes to the conclusion that the large plate-like spines situated along either side of the mid-dorsal line were alternate, not opposite as might have been expected. Furthermore, he believes that the largest spines were not, as is usually represented, situated over the pelvic region, but at the base of the tail, and that the so-called gular ossicles covered the upper surface and sides of the head and neck. The animal probably lived in low swampy ground, and from the proportions of the limbs and some other characters is almost certainly secondarily quadripedal, having been derived from a bipedal ancestry.

OBITUARY.

CHARLES CALLAWAY, M.A., D.Sc.

Born 1838. Died September 29, 1915.

(PLATE XVIII.)

We regret to record the death, in his 77th year, of Dr. Charles Callaway (the well-known Cambrian geologist and a frequent contributor for thirty years to the Geological Magazine), which occurred at his residence, Cheltenham, on September 29. Dr. Callaway was born in Bristol in 1838, and received his preliminary education in that city. Later on his studies were directed to the clerical profession and he entered Cheshunt College, near London, but shortly turned his attention to education and scientific work. He was attracted to geology in early life by collecting some fossils in the Inferior Oolite of Dundry Hill, near Bristol, and acquired practical knowledge of some branches of geology as Curator of the Museum of the Bradford Philosophical Society, as Assistant in Palæontology and Mineralogy in the New York State Museum at Albany, under Professor James Hall, and as Curator of the Sheffield Public Museum. His marriage in 1876 led to his settlement at Wellington, near the Wrekin.

His discovery of an Upper Cambrian fauna at Shineton in shales hitherto regarded as of Caradoc age was the key to most of his

subsequent work. Below these shales he found a greenish sandstone, which, by its fossil evidence and its geographic relations, he correlated with the Hollybush Sandstone of the Malvern country, then supposed to be of approximately Middle Cambrian age.

Underlying this sandstone was the Wrekin Quartzite, believed by the earlier geologists to have been metamorphosed by intrusive greenstone forming the core of the Wrekin. Meanwhile Mr. Samuel Allport had been working on the supposed irruptives, and by means of the microscope—which he was one of the first to apply to rock-structures—he proved them to be in the main of volcanic origin, consisting of interbedded ashes and rhyolites. As these strata underlay unconformably a quartzite which was not younger than Middle Cambrian, their Pre-Cambrian age became a fair inference. The subsequent demonstration by Professor Charles Lapworth of the Lower Cambrian age of the Hollybush Sandstone converted the inference into conclusive proof.[1] For this new Pre-Cambrian formation the name 'Uriconian' was proposed.

The granite rocks of the Wrekin were seen to furnish water-worn fragments to Uriconian conglomerates. Thus a second Pre-Cambrian system was recognized. The Pre-Cambrian age of the Longmynd Series also followed from the above discoveries, and the name of 'Longmyndian' was suggested for this great sedimentary formation.

Dr. Callaway extended his researches to the complicated area of Anglesey. He claimed to have proved, after work extending over twenty years, that the Ordovician strata of Northern Anglesey lay in a reflexed syncline, so that the rocks to the north could not be Ordovician, and were probably Archæan; that the crystallines of Northern Anglesey were metamorphosed sediments, that the Grey Gneiss of the southern district was a modified felsite, and that the diorite of the central complex has been modified into an elliptical dome of gneiss. In the Highlands of Scotland he took part in the work which led to the abandonment of the Murchisonian hypothesis. His researches were confirmatory of those of Nicol, but he found that the "igneous rocks" of that author were usually the Hebridean gneiss thrust over the Ordovician (Cambrian) strata by earth-movements—the zone of thrust extending from Loch Erribol on the northern coast to Ullapool. Certain problems in Ireland were investigated. The supposed metamorphic granite of Donegal was shown to be intrusive in the associated schists, the apparent bedding being the result of pressure. In County Galway it was contended that the "metamorphosed conglomerates" and other alleged sediments were plutonic rocks which had sometimes acquired parallel structures under earth-pressures. The district south of Wexford, alleged to show the

[1] In December, 1891, Professor Charles Lapworth described a new species of *Olenellus* which he dedicated to his friend, Mr. Charles Callaway, D.Sc., F.G.S., "who was the first to detect organic remains in the Comley Sandstone, and the first to demonstrate the presence of true Cambrian fossils in Shropshire generally; and whose original and sagacious inferences as to the probable Pre-Cambrian age of the unconformably underlying rocks the discovery of *Olenellus* places beyond much dispute" (p. 532. See GEOL. MAG., December, 1891, pp. 529–36, Pls. XIV and XV).

conversion of sediments into gneisses and schists, was interpreted as a pavement of rocks made up of faulted masses with no gradations between them.

The evidence, acquired in Ireland, that an apparent stratification might be produced in plutonic igneous rocks by regional pressure was subsequently seen to throw light upon the schistose and gneissic masses of Anglesey and Malvern. The gneisses and schists of the Malvern Hills were shown to have acquired their structures under pressure and shearing acting upon a complex of diorites, granites, and felsites. In the area east of the Herefordshire Beacon a second Archæan mass was discovered, which was referred to the Uriconian system. In most of these researches Dr. Callaway received great assistance from the skill and experience of Professor Bonney, who supplied descriptions of large numbers of microscopic sections of rocks.

Dr. Callaway graduated at the London University, B.A. (1862), being third in honours in Logic and Moral Philosophy; M.A. (1863), in Economical and Mental Science; B.Sc. (1872), 1st in Honours in Geology and Palæontology; D.Sc. (1878), in Geology, etc. In 1885 he received the balance of the proceeds of the Wollaston Donation Fund from the Council of the Geological Society, and in 1903 the Murchison Medal. He was made an Honorary and Corresponding Member of the Birmingham Natural History and Philosophical Society, the Liverpool Geological Society, Woolhope Naturalists' Field Club, and Cotteswold Naturalists' Field Club, being President of the last-named club from 1902–4.

Dr. Callaway retired from regular professional work and settled in Cheltenham in 1898. Advancing age rendering the activities of geological research no longer practicable, he reverted to the studies of his early life, and in 1906 he founded the Cheltenham Ethical Society, of which he became the first President. The following are a selection from Dr. Callaway's published papers:—

1874. "On the Occurrence of a Tremadoc Area near the Wrekin": Quart. Journ. Geol. Soc., Proc., March 11.

1877. "On a New Area of Upper Cambrian Rocks in South Shropshire, with a description of a New Fauna": Quart. Journ. Geol. Soc. (Nov.), pp. 652–72.

"The Migration of Species": GEOL. MAG. (Oct.), pp. 445–7.

1878. "On the Quartzites of Shropshire": Quart. Journ. Geol. Soc. (Aug.), pp. 754–63.

"The Lower Helderberg Group of New York": GEOL. MAG. (June), pp. 271–7.

1879. "The Precambrian Rocks of Shropshire," Part I: Quart. Journ. Geol. Soc. (Nov.), pp. 643–69.

"On Plagioclinal Mountains": GEOL. MAG. (May), pp. 216–21.

1880. "On a Second Precambrian Area in the Malvern Hills": Quart. Journ. Geol. Soc. (Nov.), pp. 536–9.

"New points in the Precambrian Geology of Anglesey": GEOL. MAG. (March), pp. 117–27.

1881. "The Archæan Geology of Anglesey": Quart. Journ. Geol. Soc. (May), pp. 210–38.

"The Metamorphic and Associated Rocks South of Wexford": GEOL. MAG. (Nov.), pp. 494–8.

"The Limestone of Darneo and Assynt": Quart. Journ. Geol. Soc. (May), pp. 239–44.